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OHIO IRRIGATION GUIDE, USDA, ODNR, OHIO AGRICULTURAL RESEARCH & DEVELOPMENT CENTER, OHIO STATE UNIVERSITY AND THE U.S. WEATHER BUREAU - (USED AS A REFERENCE IN OU 5 RI REPORT)

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REPORT

OHIO IRRIGATION GUIDE

PREPARED BY

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OHIO IRRIGATION GUIDE

This guide is based on best information available at this time on soils, crops and water factors necessary for the planning, design and management of sprinkler irrigation systems. With the development of more research and better instrumentation, changes may be made in future publications.

Conservation irrigation means applying irrigation water according to the needs of the crops, the water-holding capacity and the intake rate of the soil.

The guide provides information regarding the normal depth of irrigation, the gross water application, the rate of application, the maximum time allowed to complete an irrigation interval and monthly and seasonal crop water requirement.

THE NEED FOR IRRIGATION

A. Climatic Factors

Ohio has a marked diversity of climatic conditions. There is an 8-degree range in mean annual temperatures over the state - from 49° in several places in the northeast up to 57° in the extreme south. Normal annual precipitation ranges from less than 30 inches at Put-in-Bay to more than 44 inches in parts of Clinton and Highland counties. Climatic differences can be explained mainly on the basis of topographic variations and the range of latitude.

Both temperature and rainfall contribute to the demand for moisture by growing crops and the need for irrigation. Favorable temperatures are an obvious requirement for plant development, as is the availability of an adequate supply of soil moisture. It is generally conceded that growth conditions are most favorable when the level of soil moisture lies somewhere between field capacity and 50 percent of available moisture. This optimum condition is seldom maintained in Ohio throughout the growing season because summer rainfall normally is insufficient to make up for evapotranspiration. Soil moisture deficiency can be corrected by irrigation, provided its installation and operation is economically justifiable, and an adequate supply of water is available. Climatic and hydrologic factors should be considered when deciding whether or not to invest in an irrigation system.

Basic information needed includes a reasonable estimate of successive weekly amounts of water needed to maintain optimum moisture conditions in the root zone. Knowing the probable consumptive demand it is possible to determine the probability that natural rainfall will provide the required amount of water, and how much water would have to be added by irrigation in a normal season.

The normal distribution of rainfall over the state at any particular period can be found in Research Bulletins 1005 and 1017. [1/] [2/]

The typical moisture situation during spring and summer months is one of increasing deficits within the root zone. Only in the very wettest of summers is moisture maintained above the 50 percent of available moisture; and in a normal season soil moisture generally is reduced to about 20 percent of available moisture by the end of August. The need for irrigation in Ohio is dictated by this failure of natural rainfall plus stored soil moisture to supply the evapotranspiration demand for desired quality yields.

B. Typical Water Requirements of Crops Under Irrigation

Fields planted to corn in spring remain essentially bare until late June when plants have grown large enough to transpire significant amounts of water. During this period a significant amount of water is lost by surface evaporation, and extraction takes place mainly from the top foot of soil. Hence the greater part of the stored water supply remains intact for later use when the crop need for moisture is greatest. As the period of rapid growth starts about the end of June the demand for moisture due to transpiration increases until a maximum rate is attained by the third week of July. This maximum is maintained by the corn crop until the reproductive stage begins in late July or August, after which there is a graded decline.

Figure 1 gives an indication of the amount of water required every week in a normal season to maintain soil moisture above the 50 percent level of availability. These amounts are shown by the curve which peaks in July and August. Values represent estimates derived initially from lysimeter records at the ARS station near Coshocton, Ohio, and adjusted to fit the probable needs under near optimum moisture conditions. The second curve shows by weeks and percentage probability that natural rainfall will provide the indicated amounts of water each week during the season. Note that the chances are less than 50-50 throughout most of the growing season, the lowest probability being in midsummer. Although little quantitative information is available to prove it, there is reason to believe that similar relationships between evapotranspiration and effective rainfall exist for other spring-planted crops in Ohio..

C. Frost and Freezing Temperature

The length of the growing season is customarily defined as the number of days between the last killing frost in spring and the first in autumn. Since weather observers do not always agree whether to rate a given frost situation as "killing", the Weather Bureau has adopted the more objective criterion of 32° F. at the 5-foot height as the specification for a "killing frost." Figures 2 and 3 show respectively the average last dates of 32-degree temperatures in spring and the first in autumn. Note that the distribution on both maps are similar and are related to the distribution of mean growing season temperatures. Frosts occur later in spring and earlier in fall over hilly sections than in areas having more level terrain.

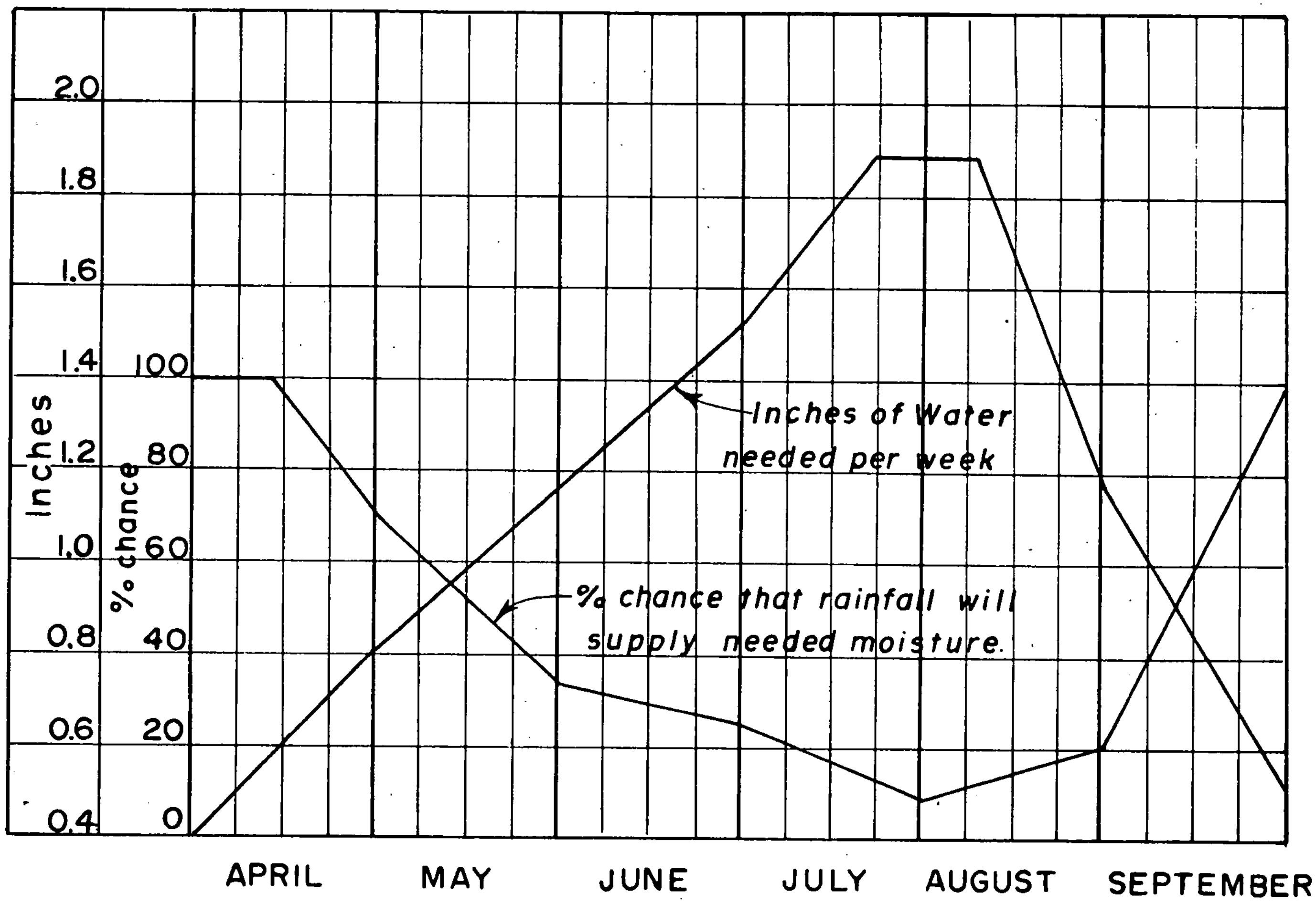

FIGURE I

Amount of water needed each week on irrigated corn to maintain soil moisture above 50% of available moisture holding capacity.

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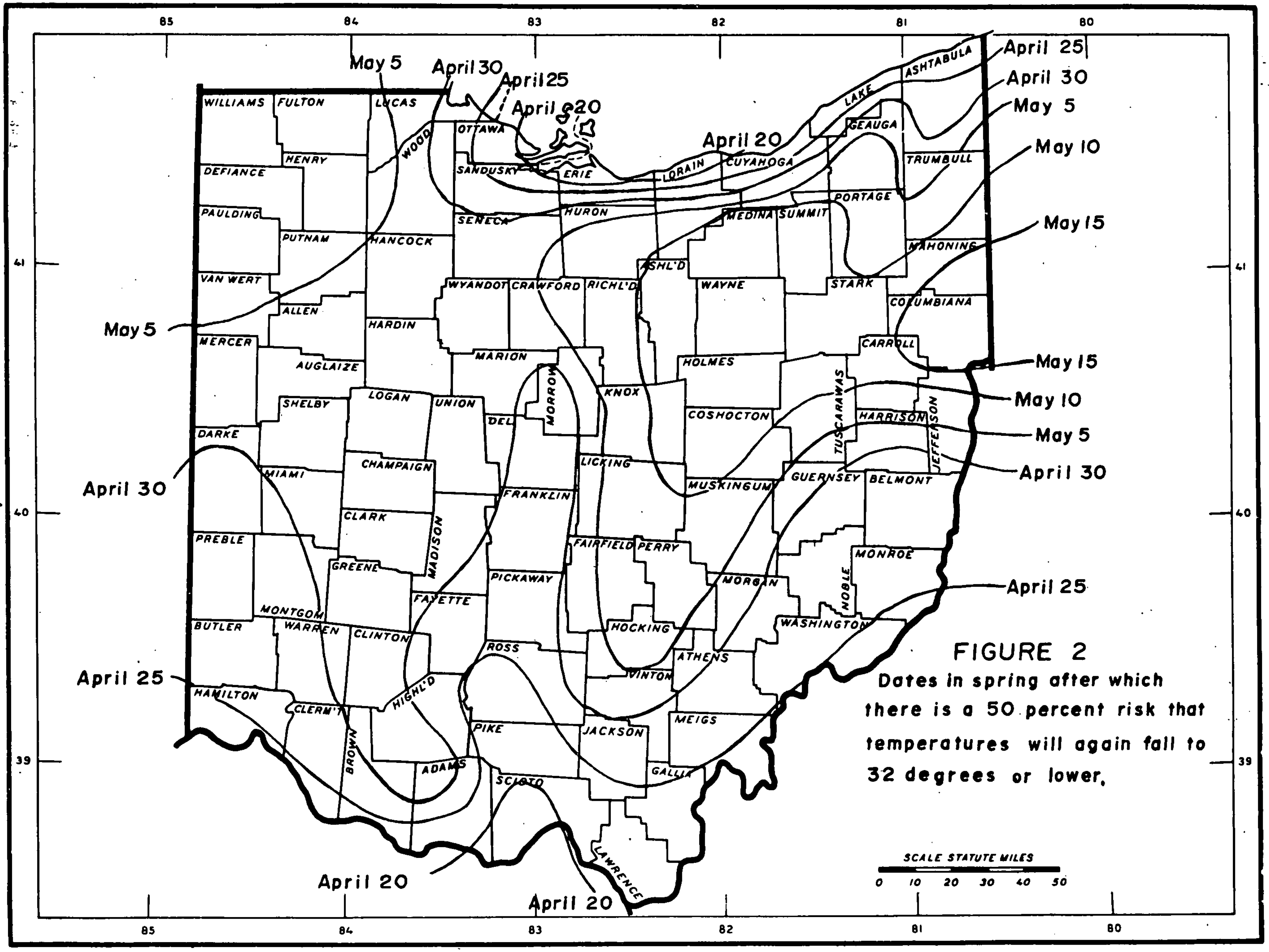

FIGURE 2
Dates in spring after which there is a 50 percent risk that temperatures will again fall to 32 degrees or lower.

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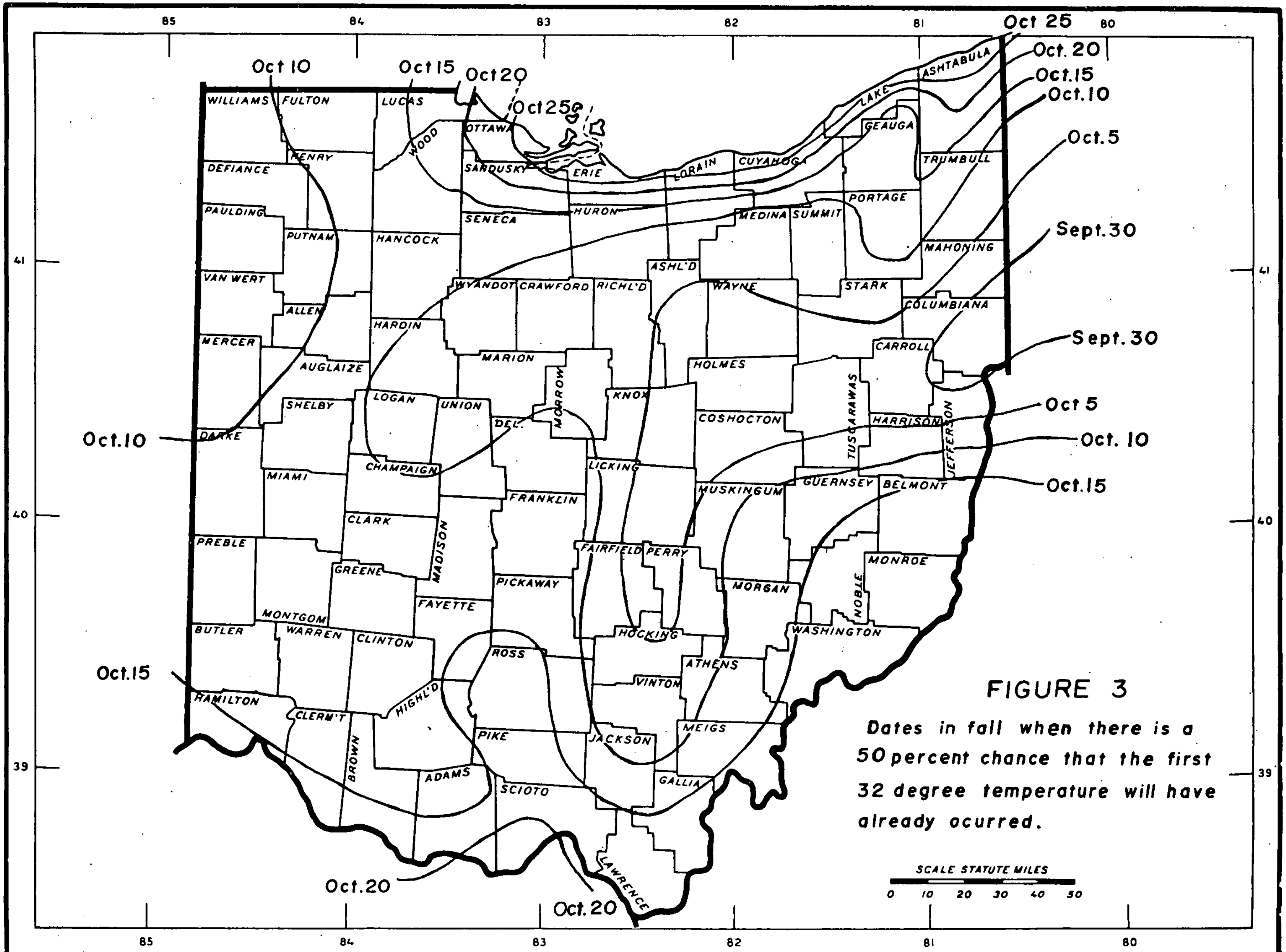

FIGURE 3

Dates in fall when there is a 50 percent chance that the first 32 degree temperature will have already ocurred.

Dates quoted on these maps are averages, representing the 50 percent probability level for 32 degree temperatures. For some purposes higher or lower temperature thresholds are more important; also information about different levels of probability may be useful. Hence, for those interested in corresponding dates for temperatures other than 32°, or in dates associated with other degrees of risk, the following conversion tables are provided.

Table 1
To convert from average dates for 32° freeze to those for indicated temperatures

Threshold temperature	Spring	Autumn
36 degrees F.	add 13 days	subtract 12 days
28 degrees F.	subtract 14 days	add 13 days
24 degrees F.	subtract 29 days	add 27 days
20 degrees F.	subtract 42 days	add 39 days
16 degrees F.	subtract 54 days	add 51 days

Table 2
To convert from 50 percent probability to other degrees of risk

Degree of Risk	Spring	Autumn
2 percent	add 26 days	subtract 24 days
25 percent	add 8 days	subtract 8 days
75 percent	subtract 8 days	add 8 days
98 percent	subtract 26 days	add 24 days

D. Economic Factors

The primary factors for a successful irrigation plan include: (1) adequate water supply which can be developed at a reasonable cost, (2) adequate labor to install and operate the irrigation system, (3) sufficient capital to provide the necessary facilities and equipment, and (4) a favorable return from irrigation. In addition to these factors other considerations are the possibility for use of the irrigation system for application of fertilizer and insecticides, for fire protection of the farmstead, and for frost protection of the crops.

(1) Water Supply
The quantity of water required for irrigation will depend largely on the length of the drought period and the crop and soils characteristics, but will usually vary from 6 to 18 inches of water per acre irrigated.

(2) Labor
Hand moved sprinkler irrigation systems have a high labor requirement, particularly with tall growing crops, such as corn. At least one man-hour of labor per acre is required to move a

sprinkler irrigation system in corn. Assuming that three irrigations are required, the total labor requirement for irrigation would be about the same as for all other tillage and harvesting operations for a crop, such as corn. Mechanical move and solid set sprinkler systems can greatly reduce the labor requirement.

(3) Capital

The capital investment for sprinkler irrigation systems will normally be from $100 to $200 per acre, but for solid set systems this cost may range from $600 to $1,000 per acre. The fixed costs, such as interest, depreciation, etc., occur each year regardless of whether the irrigation system is used. The cost of development of the water supply also must include cost items such as wells, pumps and reservoir site construction. The cost per acre will be greater on small acreages.

(4) Returns

Some additional cost in seed and fertilizer may be required for crops under irrigation. Alternate possibilities for investment should be considered in comparison with irrigation. These could be for additional fertilizer, a surface or tile drainage system, or erosion control works, such as levees along streams in flood plain areas. If optimum use is not being made of fertilizers and good drainage practices, these alternatives may prove to be more profitable.

One of the most difficult factors to evaluate is the expected increase in income from irrigation. In general, truck crops, such as strawberries, potatoes, beans and sweet corn have shown rather high returns because of the high income per acre and the increase and uniformity of crop quality. Crops such as field corn and pasture for dairy cattle have generally not shown high returns. Recent studies in Ohio have shown that sweet corn generally will give a high return, but the returns are lower for tobacco, field corn, and orchards. Higher returns may be expected from sandy soils or those which have a low water-holding capacity. These soils do not provide sufficient moisture to carry the crop through a prolonged drought period. These coarse textured soils are fortunately best suited for vegetable crops.

BASIC CONSIDERATIONS

Irrigation should be undertaken only after evaluating all factors relating to the costs and returns. In appraising potential irrigation returns, growers should recognize that the practice may be used not only to increase income, but also to facilitate better management and provide for improved operating efficiency. For the farmer, the benefit from irrigation must be sufficient to justify the cost of purchasing and operating the irrigation system and leave a reasonable return on the investment.

For the greenskeeper, park or landscape superintendent, nurseryman, and home owner, irrigation must be done to maintain the desired growth or appearance of grass, ornamental plants, flowers, and garden crops with minimum cost and effort.

To obtain the maximum benefit from irrigation, the following conditions must be considered:

A. Water Supply

Irrigation requires large volumes of water. In evaluating the water supply, the landowner should assure himself that it is (1) adequate to meet the requirements of the acreage of crops to be irrigated, (2) of suitable quality, (3) dependable, (4) economically accessible, and (5) legally available.

In general there are three sources of water for irrigation purposes. These are underground supplies pumped from wells or pits, flowing streams, and surface reservoirs.

1. Wells

The Division of Water, Ohio Department of Natural Resources, Columbus, Ohio can supply information on ground water possibilities for most areas of the state. Sometimes ground water contains salts in such high content as to make it unsuitable for irrigation. Tests should be made of the proposed water supply if water quality is questionable. It is a good practice to install a test well to determine if an adequate water supply is available.

2. Streams

Only streams that have an adequate flow during drought periods can be used as a direct source of water for irrigation. Some streams carry sewage and industrial waste that contain chemicals that may be harmful to plant growth.

3. Reservoirs

The reservoir storage capacity must be sufficient to meet crop needs, losses due to evaporation and seepage during the irrigation season, and the sediment storage requirement for the expected life of the structure. The storage requirement will vary in accordance with the needs of the different crops, the acreage to be irrigated and the anticipated recharge of the reservoir between irrigations.

B. Erosion Control

If the area under consideration is on sloping land appropriate conservation measures are needed for protection against erosion damages and possible aggravation of this hazard by irrigation. These may include such practices as contour planting, terraces, diversions, cover cropping, strip cropping and mulching.

C. Drainage

Land to be irrigated must be well drained to achieve the satisfactory results. If the land is not naturally well drained, adequate surface and internal drainage must be provided. This might include such practices as tile drains, open ditches, and land grading. Consult the Ohio Drainage Guide [3/] for additional information.

D. Fertility Management

The soil fertility program should be based on soil tests and plant analyses. Consult the current Ohio Agronomy Guide [4/] for additional information.

E. Plants and Plant Population

In order to maximize irrigation benefits, high quality seed, adapted plant varieties, and recommended plant population should be used. Consult the current Ohio Agronomy Guide for additional information.

F. Conservation Cropping System

The sequence of crops grown and the use of crop residue and cover crops are important considerations in obtaining maximum returns from the irrigation equipment. The wise use of these practices improves soil structure, tilth and intake characteristics of the soil. Good cultural practices are necessary for the control of weeds, insects and plant diseases. Consult the current Ohio Agronomy Guide[4/] for additional information.

G. System Capacity

Whatever the source of water, the system must be able to deliver an irrigation stream large enough to cover the irrigated area in the alloted interval or, conversely, the size of the irrigated area should be limited to what can be adequately irrigated by the available irrigation stream.

The rate of dependable flow required depends on the size of the area irrigated, the water requirements of the crops during periods of peak use, the efficiency of the irrigation system and the time allotted for one irrigation.

The required rate for sprinkler systems can be determined by the formula,

$$Q = \frac{453\ AD}{FH}$$

Where:

Q = the required flow in gpm
A = the irrigated area in acres
D = the gross depth of application in inches
F = the number of days to complete one irrigation over the area A
H = the actual operating hours per day

The flow, Q, must be increased to compensate for losses that occur in the water-distribution system. The flow, Q, can be reduced by operating the system at night as well as in the daylight.

Here is an example of the use of the above equation: If a farmer wants to apply 2.4 inches of water by sprinklers on a 40-acre field in 6 days, irrigating 12 hours a day, the required rate of flow would be computed as follows:

$$Q = \frac{453 \times 40 \text{ acres} \times 2.4 \text{ inches}}{6 \text{ days} \times 12 \text{ hours}} = 604 \text{ gpm}$$

Irrigating 18 hours per day, the required rate of flow would be about 400 gpm.

H. Irrigation Water Management

The practice of "Irrigation Water Management" requires that: (1) the quantity of water applied is determined by the moisture holding capacity of the soil and the needs of the crop and (2) water is applied at a rate and in such a manner that the crops can use it efficiently and significant runoff and erosion does not occur. To meet these objectives, the irrigator must have enough water to meet crop needs, an adequate system, and it must be operated properly.

IRRIGATION METHODS

There are three general methods of irrigation - sprinkler, surface and subsurface irrigation.

Almost all irrigation in Ohio is the sprinkler type, where water is distributed under pressure through a system of portable pipes and sprinkled on the crop by rotating sprinkler heads or perforated pipe. Sprinkler heads and nozzles, available in a wide variety of sizes, apply water at rates of less than 0.1 inch per hour to more than 2 inches per hour. Perforated pipe is usually limited to small areas where the soil has a high intake rate.

Sprinkler main lines are sometimes buried where the same area is irrigated year after year. Sprinkler laterals are usually moved at least once each day during the irrigation cycle. This is done by hand or with self-propelled equipment to reduce labor. Another labor-saving approach is the use of "solid set" systems where there is enough pipe to irrigate the entire area without moving any pipe. This system can readily be adapted to frost protection and crop cooling. However, due to the high initial cost its use is limited to high value crops.

Surface irrigation involves the distribution of water over the soil surface either in a sheet or in furrows. Land leveling is generally required to obtain the proper soil slope for uniform water distribution. Surface irrigation is common in the western states, but there is very little in Ohio. It may be practical here when combined with a surface drainage system on deep soils where exposure of subsoil is not a problem.

Sub-irrigation systems distribute water below the ground surface through a system of ditches or tile drains rather than on top of the ground. To be successful, the topography must be nearly level and smooth. The upper soil layers must be permeable to permit free and rapid water movement laterally and vertically. The permeable soil must be underlain by relatively impervious soil on which an artificial water table can be built up. Few areas such as this exist in Ohio. Controlled drainage of certain muck soils is one example.

DESIGN OF SPRINKLER IRRIGATION SYSTEMS

Tables 3 and 4 provide the necessary information on crops, soils and water factors necessary for the design of a sprinkler irrigation system.

<u>Table 3</u> - Moisture extraction depth and design moisture use rates of different crops for design of irrigation systems.

<u>Heading 1</u> - <u>Crops</u>

<u>Heading 2</u> - <u>Normal depth to irrigate for soils of different texture</u>. Depths are given for sandy soils and for fine and medium texture. It is the recommended depth of soil in which moisture must be kept readily available for the plant and should not be confused with the maximum root zones.

<u>Heading 3</u> - <u>Design Use Rate</u>. The design value represents the amount of water in inches per day used by the crop during the period when the maximum amount of moisture is being extracted from the soil.

TABLE 3

MOISTURE EXTRACTION DEPTH AND DESIGN MOISTURE USE RATES OF DIFFERENT CROPS FOR DESIGN OF IRRIGATION SYSTEMS

(1)	(2)		(3)
	Normal Depth to Irrigate for Soils with Texture 2/		
Crop 1/	Heavy to Fine 3/ In.	Sandy 3/ In.	Design Use Rate 4/ In./day
Truck Crops			
Beans	18	24	0.20
Beets	18	24	0.20
Cabbage	18	24	.20
Celery	6	12	.25
Cucumber & Muskmelons	18	24	.20
Lettuce	6	12	.20
Watermelons	24	36	.20
Onions, bunch	6	12	.20
Onions, dry	12	18	.20
Peas	12	24	.20
Radishes	6	12	.20
Tomatoes	24	36	.25
Corn, Sweet & Field	24	36	0.30
Grass Sods (for sale)	6	12	0.25
Potatoes	18	36	0.30
Soybeans	24	36	0.30
Sugar Beets	24	36	0.30
Tobacco	18	24	.30
Pasture and Meadow			
Shallow: Ladino clover, Red clover, Timothy,etc.	18	30	.30
Deep: Alfalfa, Brome,etc.	24	36	.30
Fruit			
Brambles	24	36	.20
Grapes	24	36	.20
Strawberries	12	18	.25
Trees	36	48	.25
Nursery	12	18	.25

1/ Values for other crops can be estimated from those given in this table.

2/ Depth of irrigation represents the soil depth from which most of the crop needs for water are supplied. It is not the root depth.

3/ The following soil groups are considered "sandy".

184	855	932	938	953	
276	922	935	952	958	9381

The following soils have sandy loam or loamy sand surface horizons: 256 and 275.

All other soil groups are "fine and medium".

4/ Average rate for several days during the period of most rapid water demand by the crop and by direct evaporation.

Table 4 - Ohio Soils, Crops and Water Factors Used in Design of Irrigation Systems.

Heading 1 - Soil Group. The soil types indicated on soil survey maps are listed in both alphabetical and numerical order in the appendix. The soil types have been grouped into the Ohio Soil Management Groups. The group numbers are indicated in this column.

Heading 2 - Description of Soil Group. A few of the dominant soils in each group are mentioned.

Heading 3 - Moisture Extraction Depth, Inches. The listed depths of 6, 12, 18, 24, 30, 36 and 48 inches are used to correspond with the normal crop moisture extraction depth groupings as shown in Table 3, heading 2. These are the depths from which essentially all of the moisture is obtained for vigorous plant growth.

Heading 4 - Available Moisture Capacity, Inches. This heading lists the total available moisture holding capacity in inches within the soil to the depth indicated in Heading 3. The available moisture for plant use is that moisture in the soils between the wilting point and field capacity. The listed values are estimates based on laboratory tests of the physical properties of major soil types and numerous field measurements of closely related soils of similar structure, texture and other profile characteristics.

Heading 5 - Irrigation Interval in Days for Different Design Use Rates The times shown are the maximum number of operating days for the system to apply the gross application on the design area at the listed design use rates. The number of days shown for each design use rate is based on a moisture use value which is 50 percent of that shown in Heading 4.

Heading 6 - Total Water Application, Inches. This is a design value of gross application based upon the available moisture (heading 4) and a system of efficiency of 70 percent. Experience has shown that a value of 50 percent of the total available moisture capacity of the soil within the effective root zone is adequate for design. A 70 percent system efficiency is used in design to compensate for uneven sprinkler distribution patterns, pipe-line leakage and evaporation losses under normal conditions.

Heading 7 - Application Rate, Inches Per Hour. This is the maximum sprinkler application rate recommended for cultivated or bare soil conditions. With adequate ground cover on flat slopes this rate may be doubled. Consideration must be given for conditions of soil structure, slope, erosion, crop rotation and plant characteristics. The design application rate selected is also influenced by operation schedules. The selected rate may be less, but should never exceed the suggested values.

TABLE 4 - OHIO SOILS CROPS AND WATER FACTORS USED IN DESIGN OF IRRIGATION SYSTEMS

(1) Soil Group	(2) Description of Soil Group	(3) Moisture Extrac. Depth in.	(4) Available Moisture Capacity in.	(5) Irrigation interval in Days for Different Design Use Rates			(6) Gross Water Applic. in.	(7) Applic. Rate in/hr.
				0.20 in/day	0.25 in/day	0.30 in/day		
275	Well drained loam or silt	6	1.1	3.0	2.4	2.0	0.9	0.5
406	loam with gravel, sand or	12	2.2	5.5	4.4	3.7	1.6	
	fractured bedrock below 20	18	3.2	8.0	6.4	5.3	2.3	
	to 36 inches, very good	24	4.2	10.5	8.4	7.0	3.0	
	underdrainage.	30	4.7	12.0	9.6	8.0	3.4	
	FOX, CHILI, WARSAW	36	5.2	13.0	10.4	8.7	3.7	
953	Well and moderately well	6	0.7	2.0	1.6	0.6	0.6	0.6
	drained loamy fine sand,	12	1.4	3.5	2.8	2.3	1.0	
	sandy loam over clay at	18	2.1	5.0	4.0	3.3	1.4	
	30 to 36 inches, slow under-	24	2.8	7.0	5.6	4.7	2.0	
	drainage.	30	3.7	9.0	7.2	6.0	2.6	
	SEWARD	36	4.6	11.5	9.2	7.7	3.3	
103	Moderately well and well	6	1.3	3.5	2.8	2.3	1.0	0.5
	drained silt loam, loam and	12	2.5	6.0	4.8	4.0	1.7	
	sandy loam, bottomland soils	18	3.6	9.0	7.2	6.0	2.6	
	subject to flooding	24	4.7	11.5	9.2	7.7	3.3	
	GENESEE, CHAGRIN	30	5.7	14.0	11.2	9.3	4.0	
		36	6.7	16.5	13.2	11.0	4.7	
		48	8.7	21.7	17.4	14.5	6.2	
274	Well and moderately well	6	1.2	3.0	2.4	2.0	0.9	0.5
404	drained silty or loamy soils	12	2.4	6.0	4.8	4.0	1.7	
P604	with favorable subsoils and	18	3.4	8.5	6.8	5.6	2.4	
	fairly good underdrainage	24	4.4	11.0	8.8	7.3	3.1	
	OCKLEY, RUSSEL, WELLSTON,	30	5.4	13.5	10.8	9.0	3.9	
	CORWIN, WEA	36	6.4	16.0	12.8	10.6	4.6	
		48*	8.4	21.0	16.8	14.0	6.0	

* Does not apply to soils in Group 404.

* Does not apply to soils in Group 404.

TABLE 4 - OHIO SOILS CROPS AND WATER FACTORS USED IN DESIGN OF IRRIGATION SYSTEMS

(1) Soil Group	(2) Description of Soil Group	(3) Moisture Extrac. Depth in.	(4) Available Moisture Capacity in.	(5) Irrigation Interval in Days for Different Design Use Rates			(6) Gross Water Applic. in.	(7) Applic. Rate in/hr.
				0.20 in/day	0.25 in/day	0.30 in/day		
484	Well and moderately well	6	1.2	3.0	2.4	2.0	0.9	0.4
604	drained silty or loamy soils	12	2.4	6.0	4.8	4.0	1.7	
6B3	with fine or moderately fine	18	3.4	8.5	6.8	5.6	2.4	
	subsoils and moderately slow	24	4.4	11.0	8.8	7.3	3.1	
	underdrainage	30	5.4	13.5	10.8	9.0	3.9	
	MIAMI, CARDINGTON, GUERNSEY	36	6.4	16.0	12.8	10.6	4.6	
713	Well and moderately well drained	6	1.2	3.0	2.4	2.0	0.9	0.4
7A3	silty or loamy soils with	12	2.4	6.0	4.8	4.0	1.7	0.3
	slowly permeable fragipans in	18	3.3	8.5	6.8	5.6	2.4	0.2
	the subsoil, typically be-	24	4.2	10.5	8.4	7.0	3.0	0.2
	ginning at 18 to 24 inches							
	below the surface.							
	CANFIELD, ROSSMOYNE, TILSIT,							
	MONONGAHELA							
443	Well and moderately well drained	6	1.2	3.0	2.4	2.0	0.9	0.4
476	soils with fine textured sub-	12	2.4	6.0	4.8	4.0	1.7	0.3
623	soils and slow underdrainage	18	3.4	8.5	6.8	5.6	2.4	0.2
703	KEENE, UPSHUR, ST. CLAIR,	24	4.4	11.0	8.8	7.3	3.1	0.2
783	JESSUP							
000	Organic soils, very poorly	6	1.5	4.0	3.2	2.7	1.1	0.8
001	drained, more than 12 inches	12	3.0	7.5	6.0	5.0	2.1	
005	or organic material, under-	18	4.5	11.5	9.2	7.7	3.3	
009	drainage slow due to water	24	6.0	15.0	12.0	10.0	4.3	
	table.							
	CARLISLE, LINWOOD							

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TABLE 4 - OHIO SOILS CROPS AND WATER FACTORS USED IN DESIGN OF IRRIGATION SYSTEMS

(1) Soil Group	(2) Description of Soil Group	(3) Moisture Extrac. Depth in.	(4) Available Moisture Capacity in.	(5) Irrigation Interval in Days for Different Design Use Rates			(6) Gross Water Applic. in.	(7) Applic. Rate in/hr.
				0.20 in/day	0.25 in/day	0.30 in/day		
932	Well to somewhat poorly drained	6	0.4	1.0	0.8	0.7	0.3	1.0
935	Loamy sand, sand or gravelly	12	0.8	2.0	1.6	1.3	0.6	
276	Soils without B horizons	18	1.0	2.5	2.0	1.7	0.7	
	having clay accumulation.	24	1.2	3.0	2.4	2.0	0.9	
	PLAINFIELD,MOROCCO,RODMAN	30	1.4	3.5	2.8	2.3	1.0	
		36	1.6	4.0	3.2	2.7	1.1	
855	Well drained loamy fine	6	0.5	1.3	1.0	0.7	0.5	1.0
1B4	Sand soils with thin bands	12	1.0	2.5	2.0	1.7	0.7	
	having small amounts of	18	1.3	3.5	2.8	2.3	1.0	
	clay and silt.	24	1.6	4.0	3.2	2.7	1.1	
	SPINKS, COLOMA	30	1.9	4.5	3.8	3.2	1.4	
		36	2.2	5.5	4.4	3.7	1.6	
		48	2.8	7.0	5.6	4.7	2.0	
256	Well drained sandy loam,	6	0.8	2.0	1.6	1.3	0.6	0.8
646	loam, silt loam, or silty	12	1.6	4.0	3.2	2.7	1.1	
S40	clay loam soils with gravel	18	2.0	5.0	4.0	3.3	1.4	
S51	and sand or fractured bed-	24*	2.4	6.0	4.8	4.0	1.7	
	rock at 10 to 20 inches.	30*	2.8	7.0	5.6	4.7	2.0	
	CASCO, CONOTTON, RITCHEY,	36*	3.2	8.0	6.4	5.3	2.3	
	DUNBRIDGE, MUSKINGUM,	48**	3.8	9.5	7.6	6.3	2.7	
	FAIRMOUNT							

* Applies to Conotton and Dunbridge only.
** Applies only to Conotton

TABLE 4 - OHIO SOILS CROPS AND WATER FACTORS USED IN DESIGN OF IRRIGATION SYSTEMS

(1) Soil Group	(2) Description of Soil Group	(3) Moisture Extrac. Depth in.	(4) Available Moisture Capacity in.	(5) Irrigation Interval in Days for Different Design Use Rates: 0.20 in/day	0.25 in/day	0.30 in/day	(6) Gross Water Applic. in.	(7) Applic. Rate in/hr.
102	Poorly to somewhat poorly	6	1.3	3.5	2.8	2.3	1.0	0.5
108	drained silt loam, or loam	12	2.5	6.5	5.2	4.3	1.9	
118	textured bottomland soils	18	3.5	9.0	7.2	6.0	2.6	
141	subject to flooding, moderately slow underdrainage	24	4.5	11.5	9.2	7.7	3.3	
	erately slow underdrainage	30	5.5	13.7	11.0	9.1	3.9	
	in absence of water table.	36	6.5	16.2	13.0	10.8	4.6	
	SHOAL, SLOAN, WAYLAND							
408	Dark colored poorly drained	6	1.3	3.5	2.8	2.3	1.0	0.4
608	silty clay soils with mod-	12	2.5	6.5	5.2	4.3	1.9	
628	erate to moderately slow	18	3.5	9.0	7.2	6.0	2.6	
648	underdrainage.	24	4.5	11.5	9.2	7.7	3.3	
	BROOKSTON, HOYTVILLE,	30	5.5	13.7	11.0	9.1	3.9	
	MILLSDALE, PEWAMO	36	6.5	16.2	13.0	10.8	4.6	
602	Light colored somewhat poor-	6	1.2	3.0	2.4	2.0	0.9	0.4
6B2	ly drained silty or loamy	12	2.4	6.0	4.8	4.0	1.7	0.3
	soils with silty clay loam to	18	3.4	8.5	6.8	5.6	2.4	0.3
	silty subsoils and moder-	24	4.4	11.0	8.8	7.3	3.1	0.3
	ately slow underdrainage.	30	5.4	13.5	10.8	9.0	3.9	0.3
	CROSBY, BLOUNT	36	6.4	16.0	12.8	11.7	4.6	0.3
392	Light colored somewhat poorly	6	1.2	3.0	2.4	2.0	0.9	0.4
712	drained silty or loamy soils	12	2.4	6.0	4.8	4.0	1.7	0.3
7A2	with slow underdrainage due	18	3.3	8.5	6.8	5.6	2.4	0.2
	to fragipans in the subsoil,	24	4.2	10.5	8.4	7.0	3.0	0.2
	typically beginning 18 to 24							
	inches below the surface.							
	AVONBURG, RAVENNA, VENANGO,							
	WADSWORTH.							

TABLE 4 - OHIO SOILS CROPS AND WATER FACTORS USED IN DESIGN OF IRRIGATION SYSTEMS

(1) Soil Group	(2) Description of Soil Group	(3) Moisture Extrac. Depth in.	(4) Available Moisture Capacity in.	(5) Irrigation Interval in Days for Different Design Use Rates [a]			(6) Gross Water Applic. in.	(7) Applic. Rate in/hr.
				0.20 in/day	0.25 in/day	0.30 in/day		
922	Poorly to somewhat poorly	6	0.6	1.5	1.2	1.0	0.4	1.0
9381	drained light colored sandy	12	1.2	3.0	2.4	2.0	0.9	
	loam or loamy sand soils	18	1.5	4.0	3.2	2.7	1.1	
	having good underdrainage	24	1.8	4.5	3.6	3.0	1.3	
	if no water table occurs	30	2.1	5.5	4.4	3.7	1.6	
	within 36 inches.	36	2.4	6.0	4.8	4.0	1.7	
	TEDROW, NEWTON	48	3.0	7.5	6.0	5.0	2.5	
938	Poorly drained, dark	6	0.7	2.0	1.6	1.3	0.6	1.0
	colored loamy fine sand or	12	1.4	3.5	2.8	2.3	1.0	
	sandy loam soils having	18	1.9	5.0	4.0	3.3	1.4	
	good underdrainage if no	24	2.4	6.0	4.8	4.0	1.7	
	water table occurs within	30	2.7	7.0	5.6	4.7	2.0	
	36 inches.	36	3.0	7.5	6.0	5.0	2.1	
	GRANBY.							
952	Poorly to somewhat poorly	6	0.8	2.0	1.6	1.3	0.6	0.6
958	drained loamy fine sand or	12	1.6	4.0	3.2	2.7	1.1	
	sandy loam with fine clay	18	2.3	6.0	4.8	4.0	1.7	
	below 20 to 36 inches, slow	24	3.0	7.5	6.0	5.0	2.1	
	underdrainage.	30	4.0	10.0	8.0	6.7	2.9	
	RIMER, WAUSEON	36	5.0	12.5	10.0	8.3	3.6	

TABLE 4 – OHIO SOILS CROPS AND WATER FACTORS USED IN DESIGN OF IRRIGATION SYSTEMS

(1) Soil Group	(2) Description of Soil Group	(3) Moisture Extrac. Depth in.	(4) Available Moisture Capacity in.	(5) Irrigation Interval in Days for Different Design Use Rates			(6) Gross Water Applic. in.	(7) Applic. Rate in/hr.
				0.20 in/day	0.25 in/day	0.30 in/day		
622	Light colored somewhat poorly	6	1.2	3.0	2.4	2.0	0.9	0.4
632	to poorly drained fine tex-	12	2.4	6.0	4.8	4.0	1.7	0.3
702	tured soils and poorly	18	3.3	8.5	6.8	5.6	2.4	0.2
751	drained medium textured	24	4.2	10.5	8.4	7.0	3.0	0.2
	soils with slow under-							
	drainage.							
	NAPPANEE, MAHONING,							
	CLERMONT, TRUMBULL							
1D2	Poorly to somewhat poorly	6	1.2	3.0	2.4	2.0	0.9	0.4
1D9	drained silty clay or clay	12	2.4	6.0	4.8	4.0	1.7	0.3
	textured bottomland soils	18	3.4	8.5	6.8	5.6	2.4	0.2
	with slow underdrainage.	24	4.4	11.0	8.8	7.3	3.0	0.2
	DEFIANCE, WABASH							
638	Dark to moderately dark	6	1.1	3.0	2.4	2.0	0.9	0.4
919	colored poorly drained	12	2.2	5.5	4.4	3.7	1.6	0.3
	silty clay or clay soils	18	3.1	8.0	6.4	5.3	2.3	0.2
	with slow underdrainage.	24	4.0	10.0	8.0	8.3	3.6	0.2
	PAULDING, TOLEDO							

Note: Column calculations: Design Use Rate for Various Crops from Table 3

$$\text{Column 5} = \frac{\text{Column 4 X 50\% depletion}}{\text{Design Use Rate}} = \frac{1.2 \text{ X } 0.5}{0.20} = 3.0$$

$$\text{Column 6} = \frac{\text{Column 4 X 50\% depletion}}{\text{70\% Application}} = \frac{1.2 \text{ X } 0.50}{.70} = 0.86 \text{ or } 0.9$$

All values rounded up to nearest tenth of a unit.

Sprinkler System Design

Example

Field No. 1	Field No. 2	Field No. 3	Field No. 4
3 Ac.	5 Ac.	10 Ac.	10 Ac.
Casco	Genesee	Miami	Brookston
Sandy loam	Silt loam	Silt loam	Silty clay loam

Crops: Tomatoes - 10 Ac., sweet corn - 10 Ac., potatoes - 5 Ac.,

Strawberries - 3 Ac.

Effective root zone depth (Table 3)

Operation conditions

System efficiency for design - 70 percent.

Daily hours of operation - 16

Planting dates cause all crops to be at design moisture use rates during the same time.

A. Allowable Time to Complete an Irrigation

Table 3, Headings 2 and 3 list the irrigation depths and design consumptive use rate respectively for the various crops. The maximum allowable time (days) to complete one irrigation cycle on each irrigation soil group is shown in Table 4, Heading 5, for the selected irrigation depth and design consumptive use rate.

Where several soils and crops are represented in the design area, and peak design-use rates for the crops occur at about the same time of year, the time allotted for completing one irrigation (F) over the design area is obtained through a weighting process. The combination of crop, soil and interval which gives the shortest irrigation interval period is the value to be used in determining the sprinkler system capacity.

B. Determining the Weighted Gross Water Application

If the design area includes several soils and crops, the gross water requirements (Acre Inches) for each crop are computed and weighted to obtain the gross depth of application. The maximum weighted application generally occurs when the deeper rooted crops are grown in the soils having the higher total moisture holding capacity.

Field	Ac.	Crop	Root Zone Depth for Irrig. 1/	Gross Water Appl. Inches 2/	Total Appl. Ac.In.	Design Interval Days 3/	Acre Days
1	3	Sweet corn	18	1.4	4.2	3	9
2	5	Potatoes	18	2.6	13.0	6	30
3	10	Tomatoes	24	3.1	31.0	9	90
4	7	Sweet corn	24	3.3	23.1	7	49
	3	Strawberries	12	1.9	5.7	5	15
	28				77.0		193

1/ Table 3, Heading 2
2/ Table 4, Heading 6
3/ Table 4, Heading 5

Note: The root zone depth for sweet corn on Field 1 is 18 inches and on Field 4 it is 24 inches. This is a soil condition in Field 1.

Weighted application time (days) = $\frac{193 \text{ Ac. Days}}{28 \text{ Ac.}}$ = 6.9 days

Use a value of 6 days. This allows a safety factor for breakdown.

Weighted gross water application = $\frac{77.0 \text{ Ac. In.}}{28 \text{ Ac.}}$ = 2.75"

The required system capacity is:

$$Qgpm = \frac{453 \text{ X Area in Acres X Gross Application in Inches}}{\text{Irrigation Interval X Operating Hours Per day}}$$

$$Q = \frac{(453)\quad(28)\quad(2.71)}{(6)\quad(16)} = 363 \text{ gpm}$$

C. Maximum Application Rate

The maximum rate of application for irrigation systems serving a complex of soils is governed by the soil with the lowest application rate. In the example, all crops are cultivated, and the maximum application rate is limited by the Miami soils in Field No. 3. The maximum rate from Table 4, Heading 7, for this soil is 0.4 inch per hour.

IRRIGATION SYSTEM MANAGEMENT

Management is a prime factor in the success of an irrigation program. The system may be the best possible design, the equipment may be the most up to date and efficient, but still success is not insured.

Labor requirements for a hand moved irrigation system is large. Often the equipment has to be operated at the same time other labor demands are at their peak. Solid set and mechanical moved systems require very little labor. The irrigator must carefully consider how operation of his type of irrigation system will fit into the total farming enterprise. He must be sure that he has the manpower available for his choice of system. Good planning and utilization of labor is essential.

Large quantities of water are required for irrigation. Therefore, efficient use of water should be the goal of an adequate program of irrigation system management. The benefits from the investment in the irrigation system, labor and irrigation water are derived from the improved quality, yield and marketing advantages that can be achieved from irrigated crops. To obtain these benefits, with efficient water use, the irrigator must answer these very pertinent questions. When should I irrigate, how much water should I apply and is the irrigation system functioning properly?

Many irrigators tend to delay irrigation in hope that rain will come. This temptation has to be overcome. A cardinal rule of the irrigator must be that he keep his eyes on the soil and plants and not on the sky. If drainage is properly cared for, as pointed out in earlier sections, no serious problems should develop.

The question "When should I irrigate?" cannot always be answered precisely. There is no set rule that applies to all situations. Several factors must be considered in each individual case, such as particular crop, stage of growth, available water supply, irrigation system capacity and other farm operations schedules.

Most crops should be irrigated before more than half of the available moisture in the crop root zone has been used. This is a good criterion for one limit of moisture depletion. Some crops, however, are thought to do beter at higher moisture levels (less moisture deficiency at time of irrigation). Therefore, one might consider that an irrigation may be needed well before half of the available moisture has been used. Authorities are not in full agreement as to what specific crops benefit from the maintenance of "high" moisture levels or what these moisture levels should be. Generally, however, one may consider the need for irrigation is doubtful for any crop until the soil moisture deficit approaches one-third of the available moisture holding capacity of the crop root zone. Some special purpose irrigations, such as for seed germination, are, of course, exceptions to this general rule.

It is not always practical and probably not desirable to maintain the same soil-moisture level throughout the growing season. Aside from the moisture needs for insuring a stand, most crops have critical periods during the growing season when good soil moisture levels must be maintained to obtain high quality yields. The critical period for most crops occurs during the part of the growing season of pod, fruit, tuber or ear formation and development. Table 5 lists the critical growth periods for a number of important crops.

Table 5
Critical Periods of Water Needs for Crops

Crop	Critical Period
Alfalfa	Start of flowering and after cutting
Apples	Bud stage and fruit enlargement
Bean, lima	No particular period
Bean, snap	Pod enlargement
Corn, sweet and field	Tasseling, silking and early stage of ear development
Cabbage	Head development
Lettuce	Head development
Melons	Blossom to harvest
Onions	Bulb enlargement
Pasture	After grazing
Peaches	Final fruit enlargement and pit hardening
Peas	Flowering and seed enlargement
Peppers	Planting to fruit set
Potatoes	Blossom to harvest
Radish	Root enlargement
Strawberries	Fruit enlargement
Tobacco	Knee high to blossom
Tomatoes	Early flowering, fruit set and enlargement

If sufficient growing season exists from time of seeding or transplant to harvest for the desired development of the crop, short periods of slight moisture stress during the early part of the growing season may not be harmful. Except for leaf or forage crops this is true for most crops. On the other hand, overstimulation of vegetative growth from a combination of high soil fertility and available soil moisture can also be objectionable. This may delay time of harvest enough to miss the period of highest fresh market demand, effect the grade for processing or cause losses on late-maturing crops from frost damage. If irrigation water supplies are limited, the best use of the irrigation water supply would be during the critical growth period of the crop.

Irrigation must begin in time so that the irrigated area can be covered before the available moisture level in the last portion of the field to be irrigated reaches a point causing unfavorable moisture stress of the crop. Normally, the system capacity and hours of operation per day should permit irrigation to begin at moisture levels between 50 and 60 percent and be completed before the 25 percent level of available moisture is reached.

Irrigation schedules often can be varied somewhat to fit other operation schedules. Many times the irrigation system is utilized on a diversity of crops which are at different stages of growth. When the available soil moisture level for each crop area is known the timing of irrigations can be varied. For example, irrigations of a particular crop may be moved ahead a day or two to facilitate spraying insecticides or herbicides.

In determining the need for irrigation one must not overlook the fact that some portion of the field may be drier than other portions. Sometimes, because of poor water distribution during a previous irrigation, the soil moisture deficiency in one portion of the field may be found to be considerably greater than in other parts of the field. Also the soil in one part of the field may have a smaller available moisture holding capacity than the soils in another part. The moisture in this soil might be depleted to the 50 percent level long before the other soils approached that level. If these kinds of critical areas are of significant size, the decision as to when to irrigate should be based on the available moisture in the drier areas.

The amount of irrigation water to apply depends on the amount that has been used by the plant and the water holding capacity of the soil. In most cases each irrigation should refill the effective root zone bringing the soil profile to field capacity. However, this is not necessary with preplant irrigations. Also, where there is danger of water logging the soil it may be desirable to refill the effective root zone to only 80% of field capacity.

From the preceding discussion it can be seen that to have efficient irrigation water management the irrigator must have some means of determining the level of available moisture in the root zone.

A rough estimate of the probable magnitude of the soil moisture deficiency can be made from a general knowledge of the pattern of consumptive use by the particular crop, if the number of days since the last irrigation or equivalent rainfall is known. For example, in an area where the irrigation guide indicates the peak period consumptive use rate of a particular crop is about two-tenths inch per day; one might, during a hot dry period, expect to find an average soil moisture deficiency of about 1½ inches some 6 or 8 days after an irrigation had been applied. During periods of more moderate weather conditions the moisture deficiency would not be expected to be so great. These kinds of estimates cannot be expected to be precise, but they are useful in determining the need of moisture measurements or in checking the reasonableness of the estimates or measurements made by other means of determining soil moisture deficiencies.

There are several methods of measuring or estimating available moisture content and each has its advantages and limitations. The following are the most commonly used:

Tensiometers require a great deal of experience to use. There are several possibilities for errors. They do not directly provide values of the amount of water held in the soil. A special moisture characteristic curve for the particular soil is needed to convert moisture tension measurements into available moisture percentages. Tensiometers do not measure the entire range of available moisture in all soils. They are best suited for use on sandy soils since in these soils a large part of the moisture available to plants is held at a tension of less than one atmosphere.

Electrical resistance instruments use the principle that a change in moisture content in the soil produces a change in the conductivity of a material in contact with the soil. Problems exist in having a material buried which responds equally well to all ranges of moisture. They are also affected by salts in the soils. Proper installation is a must. The soil must be replaced in the hole to the same density and order as the rest of the profile for the readings to be meaningful. Manufacturers' instructions must be followed carefully, and the blocks need to be calibrated in the field for each job.

Feel and appearance is not the most accurate method of moisture determination, but with training, experience and good judgement the irrigator should be able to estimate the moisture level within 10 to 15 percent. Charts are available which describe the appearance and feel of the various textures for different moisture contents.

The carbide moisture tester has proven useful in irrigation. It utilizes the principle of chemical drying of the soil sample. A reagent such as calcium carbide is mixed with the moist soil sample within a sealed chamber. The chemical reaction of the reagent and the soil moisture produces acetylene gas. The pressure of the produced gas is recorded on a gage which is calibrated to indicate the wet weight moisture percentages of the soil. Convenient tables are available to convert these values to dry weight moisture percentages. The reaction and reading normally require about three minutes.

The carbide moisture tester used in conjunction with a volumeter provides a convenient means for setting up the direct gas pressure and the Moisture Accounting methods of available moisture determinations. Once a soil characteristics sheet has been developed for a crop in a specific field, the irrigator needs only to sample the moisture in the field and read from the soil characteristics sheet the net inches of water to be applied.

The Moisture Accounting method is gaining in acceptance as a means for determining when an irrigation is needed and how much needs to be applied. It is a relatively simple bookkeeping procedure, which can be applied by the average irrigator to assist him in his moisture management and associated operations. The method utilizes two important principles:

(1) When an adequate supply of available moisture is present in the soil profile, the rate of consumptive use by a given crop depends primarily on the growth stage of the plant and the weather conditions.

(2) When the moisture content of the soil profile is know at any given time, the moisture content at any later time can be computed by crediting moisture gained from effective rainfall or irrigation and subtracting the daily moisture withdrawals during the elapsed time.

Getting accurate estimates of the day by day consumptive use rate for the crop grown has been one of the major problems with this procedure. However, use rates can be satisfactorily estimated from available data sheets. Good estimates of the consumptive use for a given day are shown in Table 6, which reflects the effect of the amount of sunshine and the stage of growth of the crop.

Table 6
EVAPOTRANSPIRATION*
Inches Per Day in Ohio

Dates		Weather (Hours of Sunshine) Cloudy (0-3)	Normal (4-10)	Bright (11-15)
April	15-30	.05	.07	.09
May	1-14	.07	.09	.12
May	15-31	.09	.12	.15
June	1-14	.11	.14	.18
June	15-30	.14	.17	.21
July	1-14	.15	.20	.24
July	15-31	.16	.20	.25
August	1-14	.15	.19	.24
August	15-31	.13	.17	.21
September	1-14	.11	.14	.18

* Estimates in this table apply to cabbage, sweet corn, field corn, popcorn, potatoes, snap beans, soybeans, sugar beets and tomatoes.

The moisture accounting method requires daily measurement of rainfall at the site. A wedge-shaped plastic rain gage is satisfactory if read carefully.

Moisture accounting computations are easiest if they are started when the soil to be irrigated is at field capacity. This usually is the day following a heavy rain or irrigation. If account is begun at other than field capacity level, the available moisture in the effective root zone must be measured or estimated. Thereafter, each day's balance of available moisture in the soil is computed by subtracting the estimated consumptive use for the day from the previous day's balance. Irrigation and rainfall, if any, are added to the previous day's balance.

When excessive rainfall causes the daily balance to exceed the field capacity level, the excess is presumed to have been runoff or lost to deep percolation. The daily balance is then recorded as the field capacity level and the new balance calculated from this value.

When the daily balance reaches the point at which soil moisture is depleted to a predetermined allowable limit, it is time to irrigate.

Moisture accounting has the advantage of requiring very little equipment and a minimum of labor. However, periodic checks with moisture measuring devices are helpful to check the accuracy of the progress with the bookkeeping procedures, especially during the critical stage of growth periods.

With any of the foregoing procedures the amount of irrigation water to be applied is the amount necessary to bring the effective root zone from the present available soil moisture level to the field capacity moisture level. Knowing the net amount of irrigation thus required, the application efficiency of the irrigation system and the area covered, the question of how much needs to be pumped or delivered is readily answered.

EXAMPLE - MOISTURE BALANCE FOR SCHEDULING IRRIGATION

Farm Sam Doe
County Franklin
Field No. 1 (NW 40 Ac.)

Soil Type Brookston Silty Clay Loam
Crop Corn Root depth 24 in.
Available Moisture Capacity 4.0 in.
Irrigate when balance is 2.4 in.

Date	Observed Sunshine Hours	Est. Daily Evapotranspiration In/day	Rainfall In.	Net Irrigation Application In.	Daily Balance In.	Remarks: (Appearance of plant, height of plant, measured evaporation, etc.)
		Balance Brought Forward --				
5-5-66						Corn planted
			none			5-5-66 thru 5-13-66
5-12-66	2	.09	2.9	—	4.00	Available Moisture Cap.
5-13-66	12	.12	.8	--	4.00	4.00 - .12 + .8 = 4.68*
5-14-66	9	.09	—	—	4.00	
5-15-66	11	.15	—	—	4.00	
5-16-66	6	.12	—	—	3.88	
5-17-66	Thru 7-8-66				--	Record not shown
7-9-66	14	.24		--	2.30	
7-10-66	11	.24	--	1.8	3.86	Pumped 2.5" @ 70% Effic.
7-11-66	6	.20		—	3.66	
7-12-66	7	.20	1.6	--	4.00	
7-13-66	12	.24		—	4.00	
7-14-66	14	.24		—	4.00	
7-15-66	13	.25		—	3.75	

*When rainfall brings the daily balance more than 0.5 inches above the available moisture capacity disregard evapotranspiration for two days.

A. Sprinkler Irrigation System Evaluation

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To evaluate the performance of sprinkler systems which are in use, the following procedure may be used.

1. The following information should be noted:

   a. The normal net irrigation to be applied.

   b. Spacing of sprinklers and laterals.

   c. Average wind velocities during sprinkling hours.

   d. Size of sprinkler nozzles.

   e. Size and type of main and lateral lines.

   f. Pressure at the pump.

   g. Pressure at first and last nozzle.

   h. Pressure at and location of high point in lateral line if of appreciable significance.

   i. Maximum length of main and laterals.

   j. Location of line in relation to field boundaries.

   k. Wetted diameter of sprinklers.

   l. Is application rate exceeding soil intake rate?

2. Proper sprinkler system operation involves the following criteria:

   a. Pressure in lateral should not vary more than plus or minus 10% from average pressure. This will assure a minimum application rate of at least 90% of maximum rate.

      (1) For sprinklers operating at pressures up to 60 psi, the spacing along lateral lines (S_l) should not exceed 50% of wetted diameter. The spacing of laterals along the main line (S_m) should not exceed 65% of wetted diameter, however, the S_m spacing should not exceed 50% of wetted diameter if average wind velocities are 5 mph, and 30% of wetted diameter if average wind velocities are greater than 10 mph.

(2) For sprinklers operating at pressures above 60 psi and the "big gun" type, the maximum diagonal distance between two sprinklers on adjacent lateral settings should not exceed two-thirds of the wetted diameter under favorable operating conditions. Where wind is a problem, the diagonal spacing should not exceed 50% of the wetted diameter for average wind velocities of 5mph, and 30% for average wind velocities greater than 10 mph.

b. The water applied by a sprinkler should disappear from the soil surface by the time the sprinkler makes a complete revolution. This observation should be made near the end of the water application period.

3. To aid the evaluation process the following relationships and tables may be used:

a. Loss in main line generally should not exceed 30% of pump pressure.

b. The average pressure of a lateral of a nearly uniform slope can be taken as the pressure at the last sprinkler plus one-fourth of pressure difference between the first and last sprinklers.
If the lateral has high or low points between the first and last sprinklers, a pressure reading should be taken at such points and the average pressure determined for each reach. The average pressure for the laterals is the average of the pressure averages of the reaches.

c. Sprinkler discharges for various pressures may be taken from manufacturer's performance tables. Table 7 may be used for nozzle combinations not found in manufacturer's performance tables. The average discharge for a lateral is the sprinkler discharge at average pressure times the number of sprinklers on the lateral.

d. Table 8 may be used to determine the application rate of sprinklers at various discharges and spacings. The hours of operation time to make the required net application for any lateral setting is required net application amount divided my minimum application rate (sprinkler having lowest pressure). This value is then divided by the sprinkler efficiency.

e. The Sprinkler System Evaluation Sheet, Form OH-ENG 137 provides an orderly means for recording evaluation data. Examination of the data will indicate if sprinkler system meets operational requirements or if further assistance by the dealer or irrigation engineer is needed to develop alternatives for correcting operational deficiencies.

TABLE 7 THEORETICAL DISCHARGE OF SPRINKLER NOZZLES

Discharge in g.p.m. for following pressures in #/sq.in.

Nozzle Dia.	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
3/32	0.8	1.0	1.1	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	-	-	-	-	-	-	-	-
7/16	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.7	-	-	-	-	-	-	-	-
1/8	1.4	1.7	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.7	-	-	-	-	-	-
9/64	1.8	2.2	2.5	2.8	3.1	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.7	-	-	-	-	-	-
5/32	2.2	2.7	3.1	3.5	3.8	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.9	6.1	6.3	-	-	-	-
11/64	2.7	3.3	3.7	4.2	4.6	5.0	5.4	5.7	6.0	6.3	6.6	6.8	7.1	7.3	7.6	-	-	-	-
3/16	3.2	3.9	4.5	5.0	5.5	6.0	6.4	6.8	7.1	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.6	-	-
13/64	3.7	4.6	5.3	5.9	6.5	7.0	7.5	7.9	8.4	8.8	9.2	9.5	9.9	10.2	10.6	10.9	11.2	-	-
7/32	4.3	5.3	6.1	6.9	7.5	8.1	8.7	9.2	9.7	10.2	10.6	11.1	11.5	11.9	12.3	12.6	13.0	13.4	13.7
15/64	5.0	6.1	7.0	7.9	8.6	9.3	10.0	10.6	11.1	11.7	12.2	12.7	13.2	13.6	14.1	14.5	14.9	15.3	15.7
1/4	5.7	6.9	8.0	9.0	9.8	10.6	11.3	12.0	12.7	13.3	13.9	14.4	15.0	15.5	16.0	16.5	16.9	17.5	17.9
17/64	6.4	7.8	9.0	10.1	11.1	12.0	12.8	13.6	14.3	15.0	15.7	16.3	16.9	17.5	18.1	18.6	19.2	19.7	20.2
9/32	7.2	8.8	10.1	11.3	12.4	13.4	14.3	15.2	16.0	16.8	17.6	18.3	19.0	19.7	20.3	20.9	21.5	22.1	22.7
19.64	8.0	9.8	11.3	12.6	13.8	15.0	16.0	16.9	17.9	18.7	19.6	20.4	21.2	21.9	22.6	23.3	24.0	24.6	25.3
5/16	8.9	10.9	12.6	14.0	15.3	16.6	17.7	18.8	19.8	20.8	21.7	22.6	23.4	24.2	25.0	25.8	26.5	27.3	28.0
21/64	9.8	12.0	13.8	15.4	16.9	18.3	19.5	20.7	21.8	22.9	23.9	24.9	25.8	26.7	27.6	28.4	29.3	30.1	30.9
11/32	10.7	13.1	15.1	16.9	18.6	20.0	21.4	22.7	23.9	25.1	26.2	27.3	28.3	29.3	30.3	31.2	32.1	33.0	33.9
23/64	11.7	14.3	16.6	18.5	20.3	21.9	23.4	24.8	26.2	27.4	28.7	29.8	31.0	32.1	33.1	34.1	35.1	36.1	37.0
3/8	12.8	15.6	18.0	21.0	22.1	23.8	25.6	27.0	28.5	29.9	31.2	32.5	33.7	34.9	36.1	37.2	38.2	39.3	40.3
25/64	13.8	16.9	19.6	21.9	23.9	25.9	27.7	29.3	30.9	32.4	33.9	35.3	36.6	37.9	39.1	40.3	41.5	42.6	43.7
13/32	-	-	21.1	23.6	25.9	28.0	29.9	31.7	33.4	35.1	36.6	38.1	39.6	41.0	42.3	43.6	44.9	46.1	47.3
27/64	-	-	22.8	25.5	27.9	30.2	32.3	34.2	36.0	37.8	39.5	41.1	42.7	44.2	45.6	47.0	48.4	49.7	50.9
7/16	-	-	-	-	30.1	32.5	34.7	36.8	38.8	40.8	42.5	44.2	45.9	47.5	49.1	50.6	52.0	53.5	54.9
29/64	-	-	-	-	32.2	34.8	37.2	39.5	41.6	43.7	45.6	47.4	49.2	51.0	52.6	54.2	55.7	57.4	58.9
15/32	-	-	-	-	-	-	39.8	42.2	44.5	46.7	48.8	50.8	52.7	54.5	56.3	58.1	59.7	61.4	63.0
31/64	-	-	-	-	-	-	42.5	45.1	47.5	49.9	52.1	54.2	56.3	58.2	60.1	62.0	63.8	65.5	67.3
1/2	-	-	-	-	-	-	-	-	50.7	53.2	55.6	57.8	60.0	62.2	64.2	66.0	68.1	70.0	71.6
17/32	-	-	-	-	-	-	-	-	55.6	58.3	60.0	63.4	65.9	68.3	70.6	72.8	75.0	77.1	79.2
9/16	-	-	-	-	-	-	-	-	-	-	68.4	71.3	74.1	77.0	79.6	82.2	84.8	87.3	89.7
5/8	-	-	-	-	-	-	-	-	-	-	82.8	86.3	89.8	93.3	96.6	99.8	102.9	106.0	109.0

$q = 29.85\ cd^2 \sqrt{p}$ where c = coeff. of discharge of nozzle (taken as 0.96 in these computations).

TABLE 8 G.P.M. CONVERTED TO APPLICATION RATE - INCHES PER HOUR

Spacing Feet	Gallons Per Minute From Each Sprinkler															
	1	2	3	4	5	6	7	8	9	10	11	12	15	18	20	25
20x20	.24	.48	.72	.96	1.20	1.44	1.68	1.92								
20x30	.16	.32	.48	.64	.80	.96	1.14	1.28	1,44	1.60	1.76	1.93				
20x40	.12	.24	.36	.48	.60	.72	.84	.96	1.08	1.20	1.32	1.45	1.81	2.17		
20x50	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	1.10	1.20	1.50	1.80	2.00	
20x60	.08	.16	.24	.32	.40	.48	.56	.64	.72	.80	.88	.96	1.20	1.44	1.60	2.00
25x25	.15	.30	.46	.61	.77	.92	1.07	1.23	1.38	1.54	1.70	1.85	2.31			
30x30	.11	.21	.32	.43	.54	.64	.70	.86	.96	1.07	1.18	1.28	1.61	1.93	2.14	
30x40		.16	.24	.32	.40	.48	.52	.64	.72	.80	.88	.96	1.20	1.45	1.61	2.01
30x50		.13	.19	.25	.32	.38	.44	.51	.57	.64	.70	.76	.96	1.15	1.28	1.60
30x60		.11	.16	.21	.27	.32	.37	.43	.48	.53	.58	.64	.80	.96	1.07	1.34
40x40		.12	.18	.24	.30	.36	.42	.48	.54	.60	.66	.72	.90	1.08	1.20	1.50
40x50		.10	.14	.19	.24	.29	.33	.38	.43	.48	.53	.58	.72	.86	.96	1.20
40x60			.12	.16	.20	.24	.28	.32	.36	.40	.44	.48	.60	.72	.80	1.00
40x80			.09	.12	.15	.18	.21	.24	.27	.30	.33	.36	.45	.54	.60	.75
50x50			.12	.15	.19	.23	.27	.31	.35	.39	.42	.46	.58	.69	.77	.96
50x60			.10	.13	.16	.19	.22	.26	.29	.32	.35	.39	.48	.58	.64	.80
50x70				.11	.14	.17	.19	.22	.25	.28	.30	.33	.41	.49	.55	.69
60x60				.11	.13	.16	.18	.21	.24	.27	.29	.32	.40	.48	.53	.67
60x70					.11	.14	.16	.18	.20	.23	.25	.27	.34	.41	.46	.57
60x80					.10	.12	.14	.16	.18	.20	.22	.24	.30	.36	.40	.50

$$I = \frac{(96.3)\ (Q)}{(S_l)\ (S_m)}$$ where

I = application rate in inches per hour
Q = sprinkler discharge in g.p.m.
S_l = spacing of sprinklers on lateral in feet
S_m = spacing of laterals along main line in feet

OH-ENG-137
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U. S. Department of Agriculture 7296
Soil Conservation Service

SPRINKLER IRRIGATION SYSTEM EVALUATION SHEET

Owner ______________________________ Work Unit ____________________

Location ____

Compiled by: ________________________ Checked by ________ Date ______

EQUIPMENT DATA

SPRINKLERS: Mfg. by ____________________ Mfg. No. _______________

Nozzle Sizes - Range _____inch Spreader ______ inch

Spacing - S_l = _______feet S_m = ________ feet

S_l - Spacing Along Laterals

S_m - Spacing of Lateral Along Main

Rectangular - ___________ Square - __________ Triangular - _________

LATERAL: Length - ____Ft. Kind of Pipe - ______ Size - ______inch

No. of Laterals - _______ No. of Sprinklers Per Lateral - _________

MAIN: Length - ____feet. Kind of Pipe - ____, Size _____inch.

PUMP: Make ____________________ Nos. ____________________________

POWER: Elec. Motor ______, Internal Combustion Engin _____,

Fuel _________.

Layout Sketch of Sprinkler System

000034

OPERATION DATA

SPRINKLER PRESSURES: (Measured by Gage With Pitot Tube)

At Main End of Lateral P_m = P ________ Psi

At Distal End of Lateral P_o = __________ Psi

AVERAGE PRESSURE: $P_a = P_o + \frac{1}{4}(P_m - P_o)$ = _________ + $\frac{1}{4}$ ________ -

_________ Psi

AVERAGE SPRINKLER DISCHARGE: qa = __________ gpm and

Wetted Diameter ________ ft. (from Mfgrs. Charts & Observation)

APPLICATION RATE: I = _______ inches per hour (From Tables)

SYSTEM CAPACITY: Q = qa x n = _____ x _______ = ________ gpm
(n = No. of Sprinklers)

PRESSURE AT PUMP: P_p = _____ Psi Length of Main to Lateral _____ feet

% of Total Pressure Loss in Main to Pump Pressure = _____ %

$$\frac{P_p - P_m \times 100}{P_p} = \_\_\_\_\_\_\_\_\_\_ \times 100 = \_\_\_\_\_\_\_\%$$

Observations:
Net irrigation desired ________ inches.
Is water being absorbed by time sprinkler making a complete revolution?
Average wind velocity during operation hours ________ mph.

Recommendations

Sprinkler irrigation systems can be used for frost protection. However, the ordinary system is limited because of the area it is able to cover with one setting of the lateral lines. For frost control, the irrigation system must have enough capacity and laterals to cover the entire area to be protected with a fine mist of water. Such systems are often called solid set systems.

Sprinkling utilizes the latent heat of fusion released when water changes from the liquid form to ice. The water is applied as a fine spray and the latent heat of fusion is released when the water freezes on the plant surface. The heat thus released maintains ice temperatures around 32° F. and the ice acts as a buffer against cooling of plant surfaces by radiation or contact with cold air. The principle is valid and the process is effective only so long as the water application and subsequent ice formation continues. Not all of the heat is retained by the ice. Some is lost to cold air in contact with the ice, and some is lost to evaporation and sublimation at the water-ice surface.

The rates of water application to provide frost protection are relatively low, ranging from 1/10 to 1/8 of an inch per hour. This relatively low application rate requires special system design of mains and laterals using low gallonage sprinklers. Clean water is also a must, since foreign material in the water can easily clog the small sprinkler orifices.

The frost control system should be turned on when air temperature at the plant level reaches 34° F. An alarm system consisting of a thermo-switch set in the field at the plant level and wired to an alarm bell in the house will warn the operator when to turn the system on.

Sprinkling should continue until the ice has melted loose from the plants. If the water supply is cut off prior to this time, the supply of heat is also cut off, and sublimation will reduce the temperature of the ice surface to the wet bulb temperature if there is sufficient wind. In dry air the wet bulb temperature may be several degrees below the dry bulb or air temperature and if the sublimation process continues over a period of time, the temperature of the entire mass of ice and plant will approach the wet bulb temperature. It is therefore necessary to continue constant application of water until the wet bulb temperature is above the critical temperature of the plant.

Frost protection with irrigation works best on low-growing crops such as strawberries and plants which are not broken by the weight of ice. The weight of the accumulated ice may often damage tall-growing vegetable plants and fruit trees.

In the evaluation, development and management of irrigation water supplies it is essential that the irrigation water requirements for various crops be known. Table 9 contains the monthly and seasonal net irrigation water requirements for the major irrigated crops in Ohio. This data was prepared using TR-21 as a guide. In determining net irrigation water requirements the ten geographical divisions of the state as shown in Figure 4 are the divisions used by the U. S. Weather Bureau.

Division averages for latitude, temperature and rainfall were used. Net irrigation water requirements were determined for each crop based upon additional assumptions as follows:

> Normal net irrigation amount - equals 50% of total available moisture capacity within the root zone depth of the crop when grown in a soil having average moisture holding capacity.
>
> Carryover soil moisture - The amount of water (inches) within the root zone depth of the soil profile that is available to the plant from soil moisture storage of winter and spring precipitation.

Table 9

Monthly and Seasonal Net Irrigation Water Requirements

OHIO

1	2					3	
	Monthly					Seasonal	
Crop, Division, Growth Period	May	Jun	Jul	Aug	Sep	N	D
Alfalfa - CH, NEH - 4/20-10/16	1.6	3.9	4.9	3.9	1.9	13.9	16.2
WC, C, SE, SW, SC, NE - 4/1-10/21	1.7	4.1	5.3	4.3	1.7	14.4	17.1
NW, NC - 4/10-10/31	1.5	4.3	5.5	4.5	2.3	15.4	16.1
Beans, Lima - SE - 6/15-9/15			2.4	3.2		3.9	5.6
NW, NE, WC, C							
CH, NEH, SW, SC			2.8	3.3		4.6	6.1
NC			3.1	3.5		5.1	6.6
Beans, Snap - 1st plant. - CH, NEH		2.2	1.6			2.8	3.8
NW, NC, NE, WC, C							
SE, SW, SC - 5/15-7/15		2.7	1.8			3.7	4.5
2nd plant. - CH, NEH			2.1	2.4		3.5	4.5
NE, SE, SW, SC			1.8	3.3		4.1	5.1
NW, NC, WC, C - 7/1-8/31			2.0	3.5		4.7	5.5
Cabbage - CH, NEH, SW	0.6	3.3	2.3			4.8	6.2
NE, WC, C, SE, SC	0.6	3.5	2.9			5.7	7.0
NW, NC - 5/1-7/31	0.6	3.7	3.1			6.0	7.4
Celery - NE, SC, C, CH							
NEH, SE, SW, SC		1.5	4.1	2.4		6.6	8.0
NW, NC - 6/1-8/31		1.4	4.5	2.6		7.2	8.5
Corn, Grain - CH, NEH - 5/20-9/30		0.4	4.3	4.5	1.4	8.7	10.6
WC, C, SE, SW, SC		0.7	4.6	4.8	1.4	9.6	11.5
NC, NE		1.0	4.9	4.8	1.7	10.6	12.4
NW - 5/1-9/15		2.4	5.6	4.9		11.1	12.9
Corn, Sweet - C, CH, NEH, SC, SE			3.0	4.4	0.3	6.0	7.7
NW, NE, WC, SW, NC - 6/15-9/13			3.5	4.7	0.3	6.9	8.5
Cucumbers - C, CH, NEH, SC, SE		0.9	3.4	2.0		4.7	6.3
NW, NC, NE, WC, SW - 6/1-8/31		1.0	3.7	2.1		5.5	6.8
Grapes - CH, NEH, SC - 5/1-9/30		1.8	2.6	2.0		4.5	6.4
NW, NC, NE, WC, C, SW, SE		1.9	2.8	2.3		5.1	7.0
Lettuce - C, CH, NEH, SC, SE			3.6	2.6		5.3	6.2
NW, NC, NE, WC, SW - 6/20-8/31			3.9	2.7		5.7	6.6
Melons - WC, C, SC, SE		1.0	3.4	3.0	0.5	5.7	7.9
NW, NC, NE		1.1	3.8	3.2	0.5	6.4	8.6
CH, NEH, SW - 5/20-9/20		1.1	3.9	3.6	0.6	6.7	9.2
Onions - NE, WC, C, CH, NEH, SC, SE	1.4	3.7	2.9			6.5	8.0
NW, NC, SW - 4/20-7/31	1.4	4.0	3.4			7.3	8.8
Orchards, w/cover - NE, C, SC, SE	0.4	3.0	3.6	3.0	0.6	8.6	10.6
NW, NC, WC, CH, NEH	0.4	3.2	4.2	3.3	0.6	9.7	11.7
SW - 5/1-9/30	1.3	3.1	3.9	3.4	0.7	9.6	12.4

See page 2 for Graphical Division Codes and explanations.

Monthly and Seasonal Net Irrigation Water Requirements

OHIO

1	2					3	
	Monthly					Seasonal	
Crop, Division, Growth Period	May	Jun	Jul	Aug	Sep	N	D
Pasture - CH, NEH - 4/5/-10/31	1.7	3.6	4.5	3.9	2.5	13.6	16.2
NW, NC, NE, WC, C, SC, SE - 4/1-10/31	1.9	3.8	4.7	4.3	2.8	14.8	17.5
SW - 3/25-10/31	3.1	3.8	4.7	4.2	2.8	16.1	18.6
Peas, Green - All divisions - 4/1-6/30	2.0	2.8				3.2	4.8
Peppers - C, CH, NEH, SC, SE		0.7	4.0	2.0		5.0	6.7
NW, NC, NE, WC, SW - 6/1-8/31		0.9	4.3	2.1		5.8	7.3
Potatoes, Early - CH, NEH		2.8	4.8	1.9		7.6	9.5
NW, NE, C, SW, SC, SE	0.3	3.0	5.1	2.1		8.5	10.5
NC, WC, - 4/20-8/20		3.2	5.6	2.2		9.1	11.0
Potatoes, Late - NW, NE, WC,							
C, CH, NEH, SW, SC, SE		0.9	4.3	4.8	1.0	8.9	11.0
NC, - 5/15-9/15		1.1	4.8	4.9	0.9	9.9	11.7
Radishes - All areas							
Plot 1	2.6	2.7	2.2	1.5	1.6		10.6
Plot 2	2.0	2.3	2.2	1.9	1.0	0.6	10.0
Plot 3	1.5	2.8	2.4	1.0	1.1	1.1	9.8
Strawberries, Early - NW, NC, NE							
WC, C, CH, NEH, SC, SE	2.8	1.2				3.1	4.0
SW - 4/15-6/15	3.6	1.0				3.7	4.6
Strawberries, Evrbrng, NE, WC							
C, CH, NEH, SC, SE	2.5	3.1				4.4	5.6
NW, NC, SW - 4/15-6/30	2.6	3.4				4.8	6.0
Tobacco - CH, NEH		1.1	4.8	2.9		7.4	8.8
C, SW, SC, SE		1.5	5.1	3.1		7.9	9.7
NW, NC, NE, WC - 5/20-8/31		1.6	5.7	3.3		8.8	10.6
Tomatoes - NE, C, CH, NEH, SC, SE		0.8	4.5	2.1		5.4	7.4
NW, NC, WC, SW - 5/20-8/31		0.9	4.8	2.6		6.4	8.3

Graphical Division Codes

NW - Northwest
NC - North Central
NE - Northeast
WC - West Central

C - Central
CH - Central Hills
NEH - Northeast Hills

SW - Southwest
SC - South Central
SE - Southeast

Heading 1 - Lists the crop, graphical division and growing period considered for the crop.

Heading 2 - Lists monthly net irrigation amounts in inches for dry seasons as defined below.

Heading 3 - Lists the normal (N) and dry (D) net irrigation requirements for the season. The seasonal values under column D are the 10% chance net irrigation water requirements for truck crops and the 20% chance net irrigation water requirement for the crops of alfalfa, corn for grain, grapes, orchards and pasture.

20% chance- Indicates net water requirement will equal or be less than the amount 8 years out of 10.

10% chance- Indicates net water requirement will equal or be less than the amount 9 years out of 10.

OHIO

OHIO

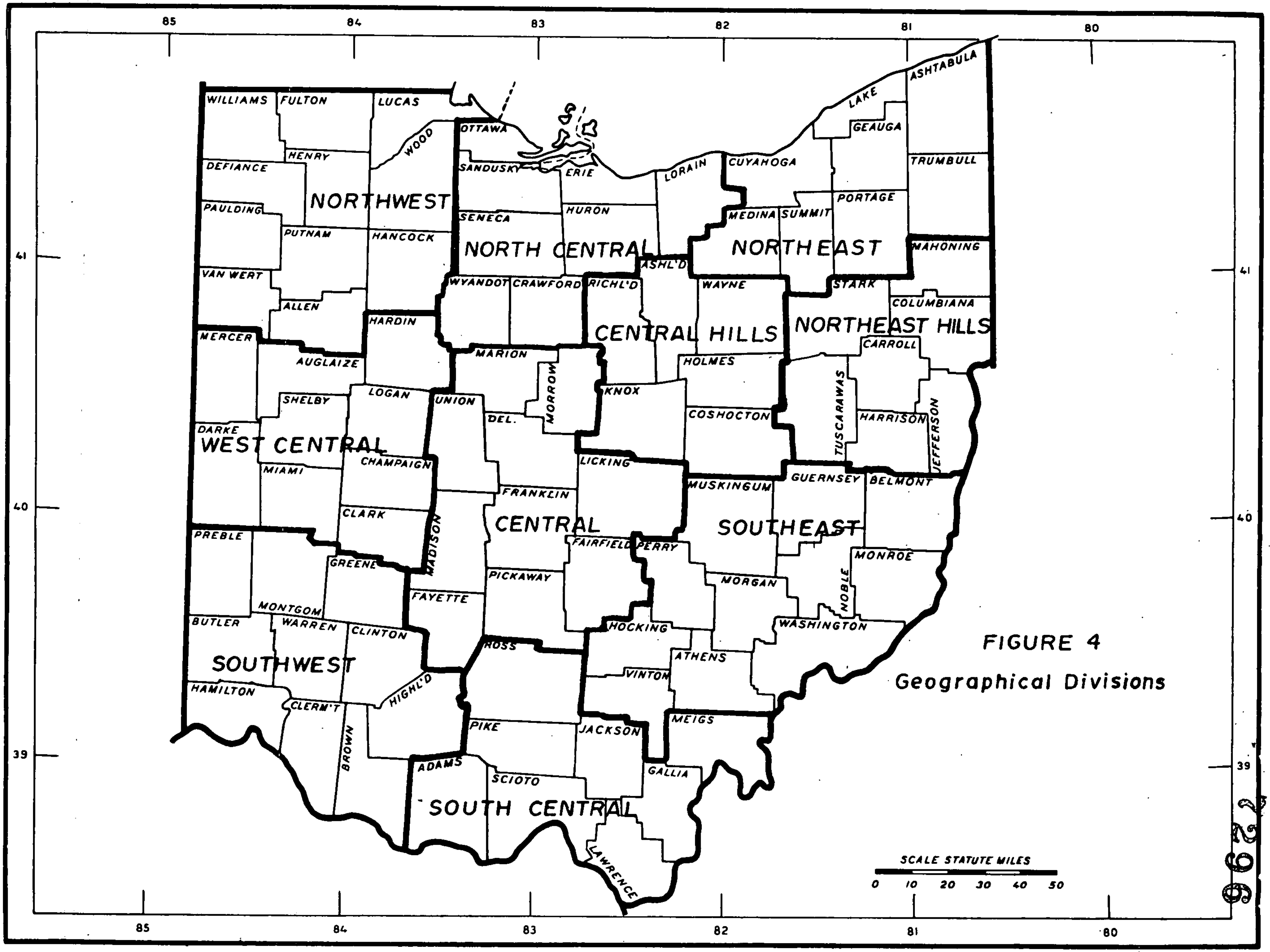

FIGURE 4
Geographical Divisions

AD-400.33
7-58

REFERENCES

1/ Research Bulletin 1005 - Monthly and Annual Precipitation Probabilities for Climatic Division in Ohio. Ohio Agricultural Research and Development Center, March 1968.

2/ Research Bulletin 1017 - Monthly and Annual Precipitation Probabilities for Selected Locations in Ohio. Ohio Agricultural Research and Development Center, March 1969.

3/ Ohio Drainage Guide, Soil Conservation Service, Ohio Agric. Exp. Station, Coop. Extension Service, The Ohio State University, Ohio Department Natural Resources, Division of Lands and Soil 1965

4/ Agronomy Guide, Current Issue, Cooperative Extension Service, The Ohio State University

APPENDIX

DEFINITIONS

Available Moisture, or available water holding capacity is the amount of water the soil will hold between field capacity and the permanent wilting point.

Field Capacity is the amount of water a well drained soil holds after free water has drained off or the maximum amount it can hold against gravity.

Consumptive use, often called evapotranspiration, includes water used by plants in transpiration and growth and that evaporated from adjacent soil and from precipitation intercepted by plant foliage.

Application Rate, is the rate that water can be applied to a soil during time required for the soil to absorb the depth of application without runoff for the conditions of soil, slope and cover.

Net Water Application, is the amount of moisture to be replaced at each irrigation and is the amount the soil can hold between field capacity and the starting moisture level. The starting moisture level is taken as 50 percent available moisture.

Gross Water Application, is the amount that must be applied to the surface to be sure enough water enters and is held in the soil to meet the net requirement for each irrigation. For design purposes, irrigation water application by sprinklers is considered to be about 70 percent efficient.

Design Use Rate, is the average for several days during the period of most rapid water demand by the crop and by direct evaporation.

Irrigation Interval, refers to the allowable number of days to complete an irrigation on the design area. It depends on the design use rate of a crop and on the amount of available moisture in the root zone (moisture extraction depth) between field capacity and the starting moisture level for irrigation.

ALPHABETICAL LISTING OF OHIO SOILS

JANUARY 1970

Soil Series (1)	Principal Mapping Number (2)	Soil Management Group (3)
Abington	279	608
Abscota	1A4	1B4
Alexandria	694	604
Alford	7K4	274
Alganseе(like)	1A2	102
Algiers	118	118
Allegheny	394	274
Allis	7C1	701
Alvin	A1(Ross Co)	275
Arkport	X8550 (Henry Co)	953
Arnheim	262	602
Ashton	1F4	274
Atherton	3T1	331
Atkins	141,161	141
Avonburg	752	392
Ayrshire(like)	7L2	602
Bartle	222	602
Beasley	544	476
Belmore	905	275
Bennington	692	6B2
Bentonville	532	392
Berks	Br(Rich.Co)	406
Berrien(like)	9C3	855
Bethel	601	331
Bewleyville(like)	575	404
Birkbeck	T3	274
Blago	3B8	919
Blanchester	757	608
Blount	6B2	6B2
Blount (like) over clay	7	622
Boehne(like)	1E5	1B4
Bogart	323	275
Bono	919	919
Boyer	Bo(Williams Co)	275
Braceville	363	713

Soil Series (1)	Principal Mapping Number (2)	Soil Management Group (3)
Bratton	574	783
Bratton(like), Rocky	S576	S51
Brooke	4546,456	486
Brooke-Upshur etc.	506	486
Brooke-Upshur, rocky	S506	S51
Brookside	4A4	783
Brookston	608,678	608
Brookston(like) 7 profile	607	608
Broughton	633	623
Bruno(like)	1B5	1B4
Burgin	578	919
Byington	593	713
Caesar	243	274
Cambridge	7A3	7A3
Cana	833,664,663	443
Canadice	971	701
Caneadea	972	702
Caneadea(like), 3 profile	973	703
Canfield	713	713
Captina	383	7A3
Cardington	693	604
Cardington(like) dark surface	P693	P604
Carlisle muck	600	000
Carlisle muck (like),silty	200	000
Casco	256	256
Castalia	1	646
Catawba(like)	1X4	604
Cavode	Cd(Columbiana Co)	392
Celina	603,6A3	604
Ceresco	1B2	102
Chagrin	124	103

Alphabetical Listing of Ohio Soils - 2

(1)	(2)	(3)
Channahon	P646	646
Chenango	365	275
Chili	325,365	275
Chilo	368	608
Cincinnati	754	604
Clarksburg	4A3	783
Claverack	963	953
Clermont	751	751
Clymer complex	46	404
Cohoctah	1B4	102
Coloma(like), 2 profile	842	922
Coloma(like), 5 profile	845	855
Colonie	9352(Ash.Co)	855
Colwood	9A8	608
Colyer	596	540
Condit	691	751
Conneaut	331S	331
Conotton	315	256
Conover,Fulton Co.	602	602
Coolville	423	443
Cope	677	608
Corwin	P603	P604
Corydon	536	S51
Coshocton etc.	446	783
Crane	302	602
Crider	524	404
Crosby	602,6A2	602
Cruze	Cw(Ross Co)	443
Damascus	321	331
Dana	P673	P604
Danbury	P912	622
Darroch	P9A2	602
Defiance	1D2	1D2
Dekalb	4063,4065	406
Dekalb,stony	4075	S40
Delmar	671	331
Del Rey	9B2	6B2

(1)	(2)	(3)
Digby	2D2	602
Dillon	939	9381
Door	Do(Logan Co)	P604
Dubois	342,352	392
Dunbridge	6463	256
Duncannon	Dt(Wash.Co)	274
Dunning	158	108
Eden	516	51S
Edenton	756	783
Edwards	300	001
Eel	103	103
Eifort	434	703
Elk	384	274
Elkins	148	108
Elkinsville	284	274
Elliott	P6B2	602
Ellsberry	513	783
Ellsworth	703	703
Elnora	9332(Ash.Co)	855
Ernest	41,42	443
Fairmount	S516	S51
Fallsburg	814	604
Fallsburg(like), 2 profile	812	702
Fallsburg(like), 3 profile	813	703
Fawcett	582,422,442	392
Fincastle	672	602
Fitchville	332	602
Foresman	P9A3	P604
Fox	275,255,615	275
Frankstown	564	404
Frankstown(like), 6 profile	566	404
Frenchtown	711,731,7A1	751
Fries	768	638
Fulton	912	622
Fulton(like), over sand	2W2	622
Galen	8532 (Erie Co)	953

(1)	(2)	(3)	(1)	(2)	(3)
Gallia	3A4	274	ILion	7A8(Ash.Co)	701
Gasconade	5166(High.Co)	646	Ionia	253	275
Geeburg	7X3	623	Iva	7K2	602
Genesee	104	103	Jacksonville	572	392
Genesee(like), over sand	1C4	1B4	Jasper	P9A4	P604
Gilford	9584(Henry Co)	958	Jessup	764	783
Gilpin	6	406	Jimtown	322	602
Gilpin stony	S406	S40	Johnsburg	402	392
Gilpin-Wharton-Keene	446	443	Joliet	648S	408
			Kalamazoo	Ka(Williams Co)	274
Ginat	361	331	Kane	302	602
Glenford	333	274	Keene	443	443
Granby lfs or coarser	938	938	Keene(deep silt variant)	444	783
Granby fsl	9384	958	Kendallville	605	604
Grayford	784	783	Kerston	100	000
Grayford (like), 2 profile	782	392	Kibbie	9A2	602
			Killbuck	137	118
Grayford (like), 3 profile	783	783	Killdeer	998	638
			Kings	219	919
Gresham	792	712	Kingsville	9314(Ash.Co)	932
Guernsey	463	783	Kokomo	609	608
Hackers	34	274	Laidig	La(Columbiana Co)	404
Hagerstown	534	404			
Haney	2D3	274	Lakin	3D5	855
Hanover	794	274	Landes	1B4	1B4
Hartshorn	154S(Monroe Co)	1B4	Latham	426	476
			Latty	9X8	919
Haskins	2A2	602	Lawrence	542	392
Haubstadt	243,353	713	Lenawee	9B8	608
Heitt	526	646	Lewisburg	6S3	6B3
Heitt rocky	S526	S51	Library	482	602
Hennepin	606	604	Lickdale	408	408
Henshaw	282	602	Licking	3B3	703
Hickory	755	6B3	Lindside	153	103
Holly	121	141	Linwood	6005	005
Homer	252	602	Lippincott	2786 (Champaign Co)	608
Hornell	7C2	701	Litz, complex	16	406
Hornell(like)	7C3	702	Litz, stony complex	17	40S
Hosmer	7H4	7A3	Lobdell	123	103
Hoytville	6288,6286	628	Lorain	978	919
Huntington	154	103	Lorenzo	P256	256

Alphabetical Listing of Ohio Soils - 4

(1)	(2)	(3)
Lorenzo-Rodman	15	256
Loudon	763	783
Loudonville	746,806,804	404
Loudonville,3 profile	743	404
Loudonville, 4 profile	744	404
Lucas	913	623
Luray	338	608
Maddox	514	404
Mahalasville	Ma(Clark Co)	608
Mahoning	702	702
Manlove	T4	274
Marengo	698,718,738	608
Markland	213,214	703
Martinsville	264	274
Massie	242	602
Maumee lfs or coarser	929	938
Maumee fsl	9294	958
McGary	212	622
Medway	203	103
Melvin	151	141
Mentor	334	274
Mermill	2A8	608
Mermill,Al over 12"depth	9	608
Metamora	9M2	952
Metea	9M32(Erie Co)	953
Miamian	604,6A4	604
Mill Creek	244	274
Millgrove	2D8	608
Millsdale	648	648
Milton	644	486
Milton-Fox over lms. rubble	3	275
Miner	707,708,7X8	919
Mitiwanga	742	702
Mitiwanga(like), I profile	741	751
Monongahela	393	7A3
Monroeville	979	919
Montgomery	218	919
Morley	6B3	6B3
Morocco	932	932
Moshannon	164	103
Mullins	401	751
Muren	7K3	274
Muskingum	406	406
Muskingum stony	S406,407	S40
Nappanee	622	622
Neopolis	959	958
Negley	355	275
Nekoosa	933	935
Neotoma	4N6	40S
Newark	152	102
Newton	9381	9381
Nicholson	573	7A3
Ninevah	294	275
Nolan	IN4	103
Oakville	925	935
Ockley	274	274
Odell	P602	602
Olmsted	328,988	608
Opequon	S536	S51
Opequon	536,(High Co)	646
Orrville	122	102
Oshtemo	3244(Erie Co)	855
Otisville	326,726	326
Ottawa(like)	9C4	855
Ottokee	923,853	855
Ottokee(like), 2 profile	852	922
Otway	546	476
Otwell	344	604
Painesville	964	953
Painesville(like) 2 profile	962	952
Painesville(like) 3 profile	963	953
Papakating	128	108
Parke	354,774	274
Parke (like), 2 profile	352	602
Parr	P604	P604
Patton	2886	608

(1)	(2)	(3)	(1)	(2)	(3)
Patton(like),8 profile	268	608	Ross	204	103
Paulding	6388	638	Rossmoyne	753	713
Pavonia	Dk(Rich Co)	406	Ruggles	984	274
Pekin	Pk(Ross Co)	274	Rush	2R4	274
Peoga	221,341	331	Russell	674	274
Pewamo	6B8	608	Sadler	403	7A3
Philo	143	103	St.Clair	623	623
Pierpont	7B3	7A3	Saranac	1S1	141
Pike	344	274	Sardinia	263	274
Pitchin	248	608	Sciotoville	363	713
Plainfield	935	935	Sebewa	258	608
Platea	7B2	7A2	Sebring	331	331
Plattville	P684		Sees	48(Monroe Co)	404
	(Warren Co)	486	Senecaville	163	103
Pope	144	103	Senecaville(like)		
			2 profile	162	102
Princeton	7L4	274	Seward	953	953
Prout	7C25(Erie C)	702	Seward,4 profile	954	953
Purdy	391	701	Shandon	2C4	953
Pyrmont	6S2	6B2	Shandon,2 profile	2C2	952
Ragsdale	T8	608	Shandon,3 profile	2C3	953
Rahm	1G2	102	Sheffield	7B1	751
Rainsboro	343	713	Shelocta	Sh(Wash Co)	443
Ramsey complex	36	S40	Shinrock	9B3	6B3
Randolph	642,682	622	Shoals	102	102
Rarden	424	443	Sidell	P674	P604
Raub	P672	602	Sisson	9A4	274
Ravenna	712	712	Sleeth	272	602
Rawson	2A3	274	Sloan	108,109	108
Rawson,4 profile	2A4	274	Spinks	855	855
Rayne	4D4	404	Stafford	8C2	922
Red Hook	362	602	Stendall	142	102
Reesville	T2	602	Summitville	493	443
Remsen	7X2	702	Sunfield	2S3(WilliamsCo)	275
Rifle	Rd(Huron Co)	009	Swanton	961	932
Reynolds	968	958	Swanton(like)		
			silty subst.	9614	938
Rimer	952	952	Swanton(like) 2		
Ritchey	646	646	profile	962	952
Ritchey(like)2 profile	18	648	Taft	382	392
Rittman	733,734	7A3	Taggart	342	712
Rodman	276,616	S51	Tawas	6001	001
Romeo	64	S51	Tedrow	922	922
Roselms	632	632	Thackery	273	274

Alphabetical Listing of Ohio Soils - 6

(1)	(2)	(3)	(1)	(2)	(3)
Tilsit	403	404	Wauseon(like) lfs		
Tioga	1T4	103	and coarser	9282	938
Tippecanoe	303	P604	Wauseon fsl over		
Titusville	793	713	silts	11	958
Toledo	916,9188,9189	919	Wawaka	X4	604
Trappist	594	406	Wayland	121	141
Trumbull	701	701	Wea	304	P604
Tuscarawas	40	443	Weikert stony complex	26	S40
Tuscola	9A3	274	Weinbach	362	712
Tygart	3B2	702	Wellston	404	404
Tygart(like)l profile	3B1	751	Westland	278	608
Tyler	392	392	Westmore	484	783
Tyner	3152(LakeCo)	935	Westmoreland	486	486
Uniontown	283	274	Westmoreland rocky	S486	S51
Upshur	474,4769	476	Wetzel	627(Union Co)	919
Upshur-Gilpin complex	496	476	Wetzel	6B7	608
Vandalia	49	443	Wharton	Wo(Columbiana Co)	443
Varna	P6B3	P604			
Vaughnsville	903	602	Wheeling	364	274
Vanango	7A2	7A2	Willette muck	6009	009
Vincent	373,374	703	Williamsburg	264	274
Wabasha	1D8,1D9	1D9	Williamson	333(Ash.Co)	713
Wadsworth	732	7A2	Wilmer	982	602
Wallington	332(Ash.Co)	712	Woodsfield	474	443
Wallkill	130	118	Woodmere	1G3	103
Warners	940,949	001	Woolper	24(Monroe Co)	404
Warsaw	305	275	Wooster	714	274
Wasepi	2G2	922	Wynn	684	486
Washtenaw	X	118	Xenia	673	274
Wauseon	928,9584	958	Zaleski	40Z	404
			Zanesville	414	404
			Zipp (like)	217	919

NUMERICAL LISTING OF OHIO SOILS

JANUARY 1970

Principal Mapping Number (1)	Soil Series (2)	Soil Management Group (3)
1	Castalia	646
3	Milton-Fox over lms rubble	275
6	Gilpin	406
7	Blount(like)over clay	622
9	Mermill,Al over 12"depth	608
11	Wauseon fsl over silts	958
15	Lorenzo-Rodman	256
16	Litz, complex	406
17	Litz,stony complex	40S
18	Ritchey(like)2 profile	648
24(MonroeCo)	Woolper	404
26	Weikert stony complex	S40
34	Hackers	274
36	Ramsey complex	S40
40	Tuscarawas	443
40Z	Zaleski	404
41	Ernest	443
42	Ernest	443
46	Clymer complex	404
48(MonroeCo)	Sees	404
49	Vandalia	443
64	Romeo	S51
100	Kerston	000
102	Shoals	102
103	Eel	103
104	Genesee	103
108	Sloan	108
109	Sloan	108
118	Algiers	118
121	Holly	141
121	Wayland	141
122	Orrville	102
123	Lobdell	103
124	Chagrin	103
128	Papakating	108
130	Wallkill	118
137	Killbuck	118
141	Atkins	141
142	Stendall	102
143	Philo	103
144	Pope	103
148	Elkins	108
151	Melvin	141
152	Newark	102
153	Lindside	103
154	Huntington	103
154S(Monroe Co)	Hartshorn	1B4
156	Dunning	108
161	Atkins	141
162	Senecaville(like), 2 profile	102
163	Senecaville	103
164	Moshannon	103
1A2	Algansee(like)	102
1A4	Abscota	1B4
1B2	Ceresco	102
1B4	Cohoctah	102
1B4	Landes	1B4
1B5	Bruno (like)	1B4
1C4	Genesee(like)over sand	1B4
1D2	Defiance	1D2
1D8	Wabasha	1D9
1D9	Wabasha	1D9
1E5	Boehne (like)	1B4
1F4	Ashton	274
1G2	Rahm	102
1G3	Woodmere	103
1N4	Nolan	103
1S1	Saranac	141
1T4	Tioga	103
1X4	Catawba (like)	604

Numerical Listing of Ohio Soils - 2

(1)	(2)	(3)	(1)	(2)	(3)
200	Carlisle muck(like)		2A3	Rawson	274
	silty	000	2A4	Rawson, 4 profile	274
203	Medway	103	2A8	Mermill	608
204	Ross	103	2C2	Shandon, 2 profile	952
212	McGary	622	2C3	Shandon, 3 profile	953
213	Markland	703	2C4	Shandon	953
214	Markland	703	2D2	Digby	602
217	Zipp (like)	919	2D3	Haney	274
218	Montgomery	919	2D8	Millgrove	608
219	Kings	919	2G2	Wasepi	922
221	Peoga	331	2R4	Rush	274
222	Bartle	602	2S3(Williams Co)	Sunfield	275
242	Massie	602	2W2	Fulton(like)over sand	622
243	Caesar	274	300	Edwards	001
243	Haubstadt	713	302	Crane	602
244	Mill Creek	274	302	Kane	602
248	Pitchin	608	303	Tippecanoe	P604
252	Homer	602	304	Wea	P604
253	Ionia	275	305	Warsaw	275
255	Fox	275	315	Conotton	256
256	Casco	256	3152(Lake Co)	Tyner	935
258	Sebewa	608	321	Damascus	331
262	Arnheim	602	322	Jimtown	602
263	Sardinia	274	323	Bogart	275
264	Martinsville	274	3244(Erie Co)	Oshtemo	855
264	Williamsburg	274	325	Chili	275
268	Patton(like)8 profile	608	326	Otisville	326
272	Sleeth	602	328	Olmsted	608
273	Thackery	274	331	Sebring	331
274	Ockley	274	331S	Conneaut	331
275	Fox	275	332	Fitchville	602
276	Rodman	S51	332(Ash.Co)	Wallington	712
278	Westland	608	333	Glenford	274
2786(Champaign Co)	Lippincott	608	333(Ash.Co)	Williamson	713
279	Abington	608	334	Mentor	274
282	Henshaw	602	338	Luray	608
283	Uniontown	274	341	Peoga	331
284	Elkinsville	274	342	Dubois	392
2886	Patton	608	342	Taggart	712
294	Ninevah	275	343	Rainsboro	713
2A2	Haskins	602	344	Otwell	604

Numerical Listing of Ohio Soils - 3

(1)	(2)	(3)	(1)	(2)	(3)
344	Pike	274	4075	Dekalb stony	S40
352	Dubois	392	408	Lickdale	408
352	Parke(like)2 profile	602	414	Zanesville	404
353	Haubstadt	713	422	Fawcett	392
354	Parke	274	423	Coolville	443
355	Negley	275	424	Rarden	443
361	Ginat	331	426	Latham	476
362	Red Hook	602	434	Eifort	703
362	Weinbach	712	442	Fawcett	392
363	Braceville	713	443	Keene	443
363	Sciotoville	713	444	Keene(deep silt variant)	783
364	Wheeling	274			
365	Chenango	275	446	Coshocton, etc	783
365	Chili	275	446	Gilpin-Wharton-Keene	443
368	Chilo	608	4546	Brooke	486
373	Vincent	703	456	Brooke	486
374	Vincent	703	463	Guernsey	783
382	Taft	392	474	Upshur	476
383	Captina	7A3	474	Woodsfield	443
384	Elk	274	4769	Upshur	476
391	Purdy	701	482	Library	602
392	Tyler	392	484	Westmore	783
393	Monongahela	7A3	486	Westmoreland	486
394	Allegheny	274	493	Summitville	443
3A4	Gallia	274	496	Upshur-Gilpin complex	476
3B1	Tygart(like)1 profile	751	4A3	Clarksburg	783
3B2	Tygart	702	4A4	Brookside	783
3B3	Licking	703	4D4	Rayne	404
3B8	Blago	919	4N6	Neotoma	40S
3D5	Lakin	855	506	Brooke-Upshur etc.	486
3T1	Atherton	331	513	Ellsberry	783
401	Mullins	751	514	Maddox	404
402	Johnsburg	392	516	Eden	51S
403	Sadler	7A3	5166(High.Co)	Gasconade	646
403	Tilsit	404	524	Crider	404
404	Wellston	404	526	Heitt	646
406	Muskingum	406	532	Bentonville	392
4063	Dekalb	406	534	Hagerstown	404
4065	Dekalb	406	536	Corydon	S51
407	Muskingum stony	S40	536(High.Co)	Opequon	646

Numerical Listing of Ohio Soils - 4

(1)	(2)	(3)	(1)	(2)	(3)
542	Lawrence	392	646	Ritchey	646
544	Beasley	476	6463	Dunbridge	256
546	Otway	476	648	Millsdale	648
564	Frankstown	404	648S	Joliet	408
566	Frankstown(like), 6 profile	404	663	Cana	443
572	Jacksonville	392	664	Cana	443
573	Nicholson	7A3	671	Delmar	331
574	Bratton	783	672	Fincastle	602
575	Bewleyville(like)	404	673	Xenia	274
578	Burgin	919	674	Russell	274
582	Fawcett	392	677	Cope	608
593	Byington	713	678	Brookston	608
594	Trappist	406	682	Randolph	622
596	Colyer	540	684	Wynn	486
600	Carlisle muck	000	691	Condit	751
6001	Tawas	001	692	Bennington	6B2
6005	Linwood	005	693	Cardington	604
6009	Willette muck	009	694	Alexandria	604
601	Bethel	331	698	Marengo	608
602	Conover(Fulton Co)	602	6A2	Crosby	602
602	Crosby	602	6A3	Celina	604
603	Celina	604	6A4	Miamian	604
604	Miamian	604	6B2	Blount	6B2
605	Kendallville	604	6B3	Morley	6B3
606	Hennepin	604	6B7(Union Co)	Wetzel	608
607	Brookston(like)7 profile	608	6B8	Pewamo	608
608	Brookston	608	6S2	Pyrmont	6B2
609	Kokomo	608	6S3	Lewisburg	6B3
615	Fox	275	701	Trumbull	701
616	Rodman	S51	702	Mahoning	702
622	Nappanee	622	703	Ellsworth	703
623	St. Clair	623	707	Miner	919
627	Wetzel	919	708	Miner	919
6286	Hoytville	628	711	Frenchtown	751
6288	Hoytville	628	712	Ravenna	712
632	Roselms	632	713	Canfield	713
633	Broughton	623	714	Wooster	274
6388	Paulding	638	718	Marengo	608
642	Randolph	622	726	Otisville	326
644	Milton	486	731	Frenchtown	751

(1)	(2)	(3)
732	Wadsworth	7A2
733	Rittman	7A3
734	Rittman	7A3
738	Morengo	608
741	Mitiwanga (like), 1 profile	751
742	Mitiwanga	702
743	Loudonville, 3 profile	404
744	Loudonville, 4 profile	404
746	Loudonville	404
751	Clermont	751
752	Avonburg	392
753	Rossmoyne	713
754	Cincinnati	604
755(Clermont Co)	Hickory	6B3
756	Edenton	783
757	Blanchester	608
763	Loudon	783
764	Jessup	783
774	Parke	274
782	Grayford (like), 2 profile	392
783	Grayford (like), 3 profile	783
784	Grayford	783
792	Gresham	712
793	Titusville	713
794	Hanover	274
7A1	Frenchtown	751
7A2	Venango	7A2
7A3	Cambridge	7A3
7A8(Ash Co)	Ilion	701
7B1	Sheffield	751
7B2	Platea	7A2
7B3	Pierpont	7A3
7C1	Allis	701
7C2	Hornell	701

(1)	(2)	(3)
7C25(Erie Co)	Prout	702
7C3	Hornell (like)	702
7C8	Fries	638
7H4	Hosmer	7A3
7K2	Iva	602
7K3	Muren	274
7K4	Alford	274
7L2	Ayrshire (like)	602
7L4	Princeton	274
7X2	Remsen	702
7X3	Geeburg	623
7X8	Miner	919
804	Loudonville	404
806	Loudonville	404
812	Fallsburg (like), 2 profile	702
813	Fallsburg (like), 3 profile	703
814	Fallsburg	604
833	Cana	443
842	Coloma (like), 2 profile	922
845	Coloma (like), 5 profile	855
852	Ohokee (like), 2 profile	922
853	Ohokee	855
8532 (Erie Co)	Galen	953
855	Spinks	855
8C2	Stafford	922
903	Vaughnsville	602
905	Belmore	275
912	Fulton	622
913	Lucas	623
918	Toledo	919
9188	Toledo	919
9189	Toledo	919
919	Bono	919
922	Tedrow	922
923	Ohokee	855

7296

(1)	(2)	(3)
925	Oakville	935
928	Wauseon	958
9282	Wauseon (like), lfs & coarser	938
929	Maumee lfs or coarser	938
9294	Maumee fsl	958
9314(Ash Co)	Kingsville	932
932	Morocco	932
933	Nekoosa	935
9332(Ash Co)	Elnora	855
935	Plainfield	935
9352(Ash Co)	Colonie	855
938	Granby lfs or coarser	938
9381	Newton	9381
9384	Granby, fsl	958
939	Dillon	9381
940	Warners	001
949	Warners	001
952	Rimer	952
953	Seward	953
954	Seward,4 profile	953
9584(Henry Co)	Gilford	958
9584	Wauseon	958
959	Neapolis	958
961	Swanton	932
9614	Swanton (like), silty subst.	938
962	Painesville (like) 2 profile	952
962	Swanton (like), 2 profile	952
963	Clarerack	953
963	Painesville(like) 3 profile	953
964	Painesville	953
968	Reynolds	958
971	Canadice	701
972	Caneadea	702
973	Caneadea (like), 3 profile	703
978	Lorain	919

(1)	(2)	(3)
979	Monroeville	919
982	Wilmer	602
984	Ruggles	274
988	Olmsted	608
998	Killdeer	638
9A2	Kibbie	602
9A3	Tuscola	274
9A4	Sisson	274
9A8	Colwood	608
9B2	Del Rey	6B2
9B3	Shinrock	6B3
9B8	Lenawee	608
9C3	Berrien (like)	855
9C4	Ohawa (like)	855
9M2	Metamora	952
9M32(Erie Co)	Metea	953
9X8	Latty	919
X	Washtenaw	118
Al (Ross Co)	Alvin	275
Bo (Williams Co)	Boyer	275
Br (Rich. Co)	Berks	406
Cd(Columbiana Co)	Carode	392
Cw (Ross Co)	Cruze	443
Dk (Rich.Co)	Pavonia	406
Do (Logan Co)	Door	P604
Dt (Wash.Co)	Duncannon	274
Ka (Williams Co)	Kalamazoo	274
La(Columbiana Co)	Laidig	404
Ma (Clark Co)	Mahalasville	608
Pk (Ross Co)	Pekin	274
Rd (Huron Co)	Rifle	009
Sh (Wash. Co)	Shelocta	443
Wo(Columbiana Co)	Wharton	443
T2	Reesville	602
T3	Birkbeck	274
T4	Manlove	274
T8	Ragsdale	608
X4	Wawaka	604
P256	Lorenzo	256
P602	Odell	602
P603	Corwin	P604

(1)	(2)	(3)
P604	Parr	P604
P646	Channahon	646
P672	Raub	602
P673	Dana	P604
P674	Sidell	P604
P684(Warren Co)	Plattville	486
P693	Cardington (like) dark surface	P604
P912	Danbury	622
P6B2	Elliott	602
P6B3	Varna	P604
P9Az	Darroch	602
P9A3	Foresman	P604
P9A4	Jasper	P604
S406	Gilpin stony	S40
S406	Muskingum stony	S40
S486	Westmoreland rocky	S51
5506	Brooke-Upshur rocky	S51
S516	Fairmount	S51
S526	Heitt rocky	S51
S536 (High.Co)	Opequon	S51
S576	Bratton (like), rocky	S51
X8550 (Henry Co)	Arkport	953

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